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IMPROVED GOLD-REDUCING MACHINERY.

We give engravings of some gold-reducing machinery constructed by Messrs Thomas B. Jordan & Son, of 52 Gracechurch Street, London, E. C., Fig. 1 showing the general arrangement of a gold reducing mill, while the remaining illustrations represent details to which we shall refer in due course.

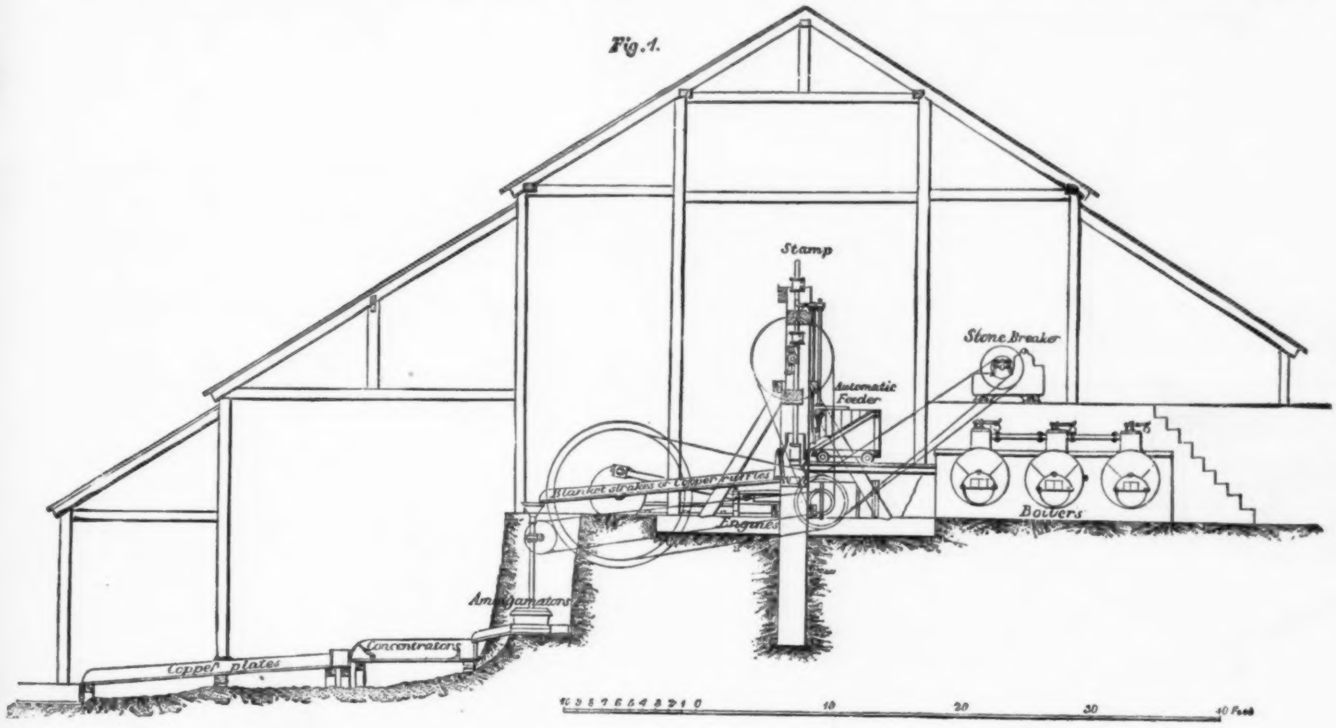
Fig. 2, on this page, shows a stamping mill of the most approved Californian type, this mill having ten stamping heads mounted in wooden framing such as is generally adopted in California, and specially suitable for localities where timber is abundant for first erection and subsequent repairs. Indeed, by many engineers timber framing is preferred to iron on account of its greater elasticity and immunity from possible fracture. The mounting represented in Fig. 2 also admits of ready repair by an ordinary carpenter.

Figs. 4 and 5, next page, illustrate similar stamps mounted with metal framing, the side struts being of cast iron and the main supports of wrought iron, firmly bolted together as shown; this makes an exceedingly rigid and strong frame, while the weight is reduced to a minimum. These stamps are illustrated as being worked by a turbine, the motion being transmitted by gearing, each set of five heads being an independent machine.

Fig. 6 shows a section of the mortar box used for wet crushing, this box being of solid cast iron of a homogeneous mixture; it weighs from 30 cwt. to 40 cwt., according to the weight of the lifts intended to work in it, and it is constructed to receive five heads, as shown by Figs. 2 and 5. On either side of the anvils or dies are seatings extending the whole length of the mortar to receive amalgamated copper plates for the purpose of arresting as much gold as possible at this stage. It will be seen from the section that the sides of this mortar are so formed, and of sufficient height, as to prevent any loss or inconvenience from splashing; for some of the harder kinds of quartz the inner sides of these mortar boxes are lined with steel plates at the points of wear; these plates are renewable and protect the casting.

Under conditions of difficult transit the makers construct their mortars in sections, the lower portion on bed being in

Fig. 1.



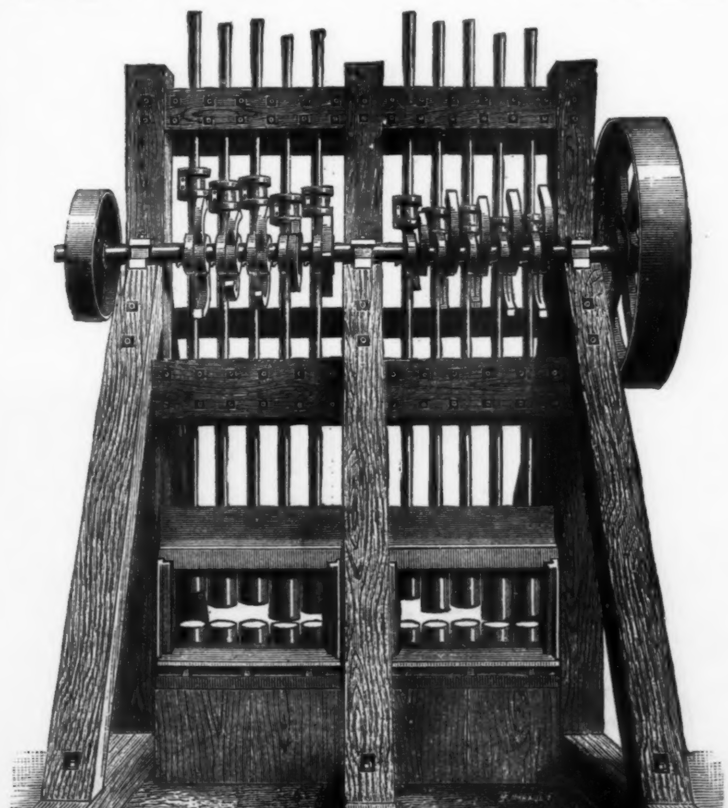
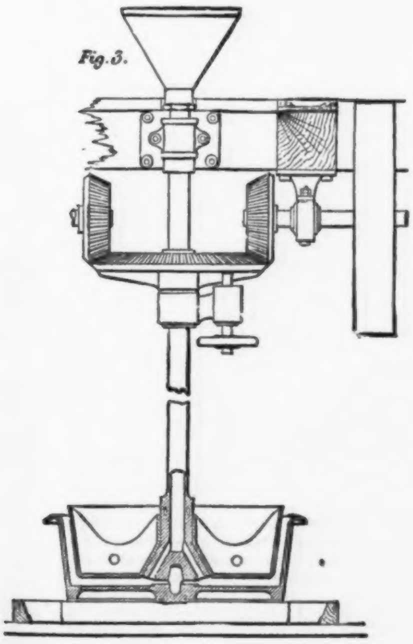


Fig. 3.



IMPROVED GOLD-REDUCING MACHINERY.

two parts of cast iron firmly bolted together, side play being prevented by a bar of wrought iron fitted and securely fastened into a groove underneath and at right angles to the joint, the bolts being turned to fit the bolt holes. The upper part of this sectional mortar box is constructed of steel plates and wrought-iron top, securely fastened at the corners by strong angle iron. It should be remarked, however, that solid boxes are for obvious reasons far preferable when circumstances will admit of their use, greater simplicity and durability being strong recommendations when the average conditions of gold mining are considered.

The stems of the stamps (see *a a*, Fig. 8) are $3\frac{1}{4}$ inches in diameter, of solid wrought iron turned from end to end and polished to gauge, both ends being coned to receive the stamp-head, *c*, which is of solid cast iron, turned, bored, and fitted to gauge, a wrought-iron ring being shrunk on its lower end to resist the wedging action of the shoe, *d*. This shoe, together with the die or anvil, *e e*, Fig. 8, is made either of cast crucible steel, or of a special mixture of hard cast iron; the latter is found to wear as long as steel, and is slightly cheaper for renewals.

The tappets, *b b*, Fig. 8, are of hard cast iron, securely fastened to the stems by steel gibs and cotters; this mode of fixing admits of easy adjustment, while the tappet is not liable to shift its position on the stem. This form of tappet has entirely taken the place of the old-fashioned screw adjustment, which has a great tendency to get out of order, and when worn involves extensive repairs, or entire renewal.

The cams (see Fig. 7) are of hard cast iron or steel, the bosses being strengthened by shrinking on a wrought iron ring; each cam is bored to fit the cam shaft, which is 5 inches in diameter, turned and polished to gauge, and of the best scrap iron, supported by three pedestals (for every set of ten heads), these pedestals being fitted with massive brass bottom steps.

The cam shaft is driven from a line shaft by one pulley for each set of five or ten heads, this pulley being $6\frac{1}{4}$ feet in diameter and 12 inches face. All details are turned, bored, and fitted to gauge, and are interchangeable, no delay is therefore occasioned when putting in renewals.

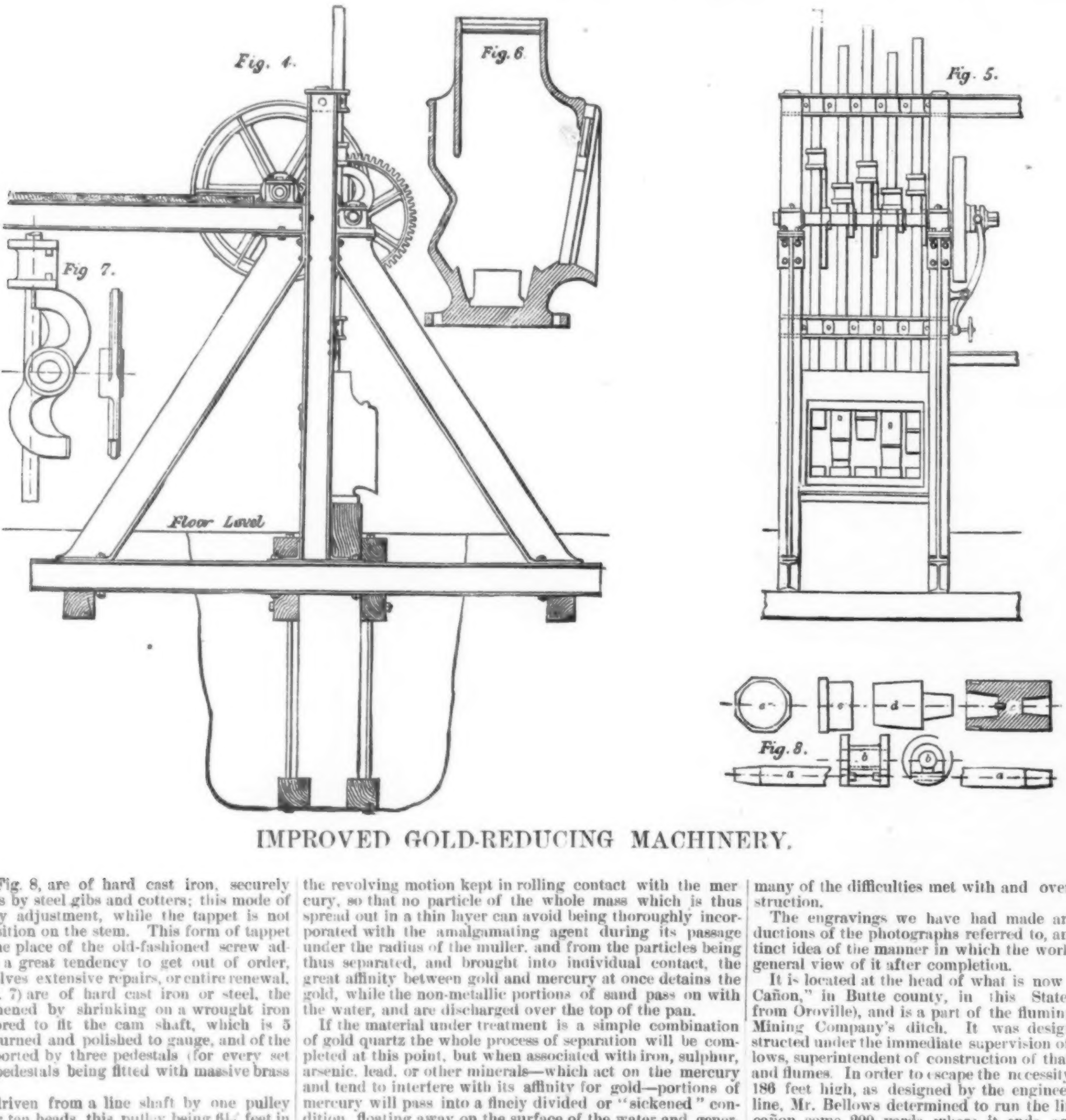
The weight of lift and amount of fall of the stamp heads varies with the work required to be done, those illustrated having a fall of 10 inches to 12 inches, each lift weighing seven hundredweight. Each head of stamp takes from $1\frac{1}{8}$ to $1\frac{1}{4}$ horse power to drive it, depending on the means used for transmitting the power, whether gearing or belting. The average produce per head is from 2 to $2\frac{1}{2}$ tons per day of twenty-four hours of hard quartz through a fine mesh.

The screens or discharge gratings extend the whole length of the box in one piece, so as to obtain the greatest possible discharge area. The mesh and material of which they are made varies according to the description of quartz to be treated. Steel, copper, or Russian iron plates are suitable for meshes from 80 to 200 holes to the square inch, and especially for dry crushing when extra strong gratings are requisite. Strong steel wire cloth or gauze, however, has the advantage of presenting a far greater discharge surface than is possible with plates, whether punched with holes or slots, and consequently this form of screen allows the stamps to do much better duty, the rate at which good stamps are capable of reducing the quartz being always greater than the possible rate of discharge; it may be remarked, however, that a stamping mill of the construction illustrated has, with fine steel wire gratings, reached a maximum of three tons of hard quartz per head per twenty-four hours, the rate of working being 75 to 80 blows per minute.

Fig. 1 is, as we have already mentioned, a section showing a general arrangement of a gold-reducing mill. The rock is prepared for the stamps by the stonebreaker, by which the rock should be reduced to about one-half inch cube; a 12 inch ×9 inch breaker of the improved type is capable of crushing sufficient ore to feed thirty to forty head of stamps, and should be fed at a suitable rate for the number of heads employed. The quartz passes direct from the breaker into the automatic feeder, and thence into the stamp boxes.

From the stamps the crushed ore is carried by a suitable stream of water over inclined strakes covered with blankets or copper plates, as the nature of the ore may require, and here certain proportions of the rich particles are arrested, the auriferous sand passing on into the hydraulic amalgamators (see Fig. 3), where it meets with a further supply of water made to whirl round the inside of the hopper, and thus avoid all possibility of lodgment; it then passes down the stand-pipe into the amalgamating pan, which is formed of two parts, the outer one being a pan of cast iron containing about 3 cwt. of mercury, and the inner pan or muller, which is fixed to the stand-pipe, revolving slowly in the mercury. The bottom of this inner pan or muller is immersed in the mercury about an inch below its surface; the sand and water pass down the stand-pipe under pressure of the column and are forced between the bottom surface of the muller and the mercury, the particles of the sand are by the revolving motion kept in rolling contact with the mercury, so that no particle of the whole mass which is thus spread out in a thin layer can avoid being thoroughly incorporated with the amalgamating agent during its passage under the radius of the muller, and from the particles being thus separated, and brought into individual contact, the great affinity between gold and mercury at once detains the gold, while the non-metallic portions of sand pass on with the water, and are discharged over the top of the pan.

If the material under treatment is a simple combination of gold quartz the whole process of separation will be completed at this point, but when associated with iron, sulphur, arsenic, lead, or other minerals—which act on the mercury and tend to interfere with its affinity for gold—portions of mercury will pass into a finely divided or "sickened" condition, floating away on the surface of the water and generally carrying gold; this rich combination is partly arrested by copper riffles, over which it flows to the concentrators (Fig. 1), where it is effectually separated from the sand which flows with it from the amalgamators, the sand passing to ordinary "bubbles" or catch-pits.—*Engineering.*



IMPROVED GOLD-REDUCING MACHINERY.

MINING FLUMES.

IN the mountains of California, where water is stored in very large quantities for use during the year in hydraulic mining, very many engineering difficulties are met with in conveying it to the point of use. This is due to the rugged character of the country, formed as it is of steep mountains, high ridges, deep cañons, gulches dry for months and then filled suddenly with foaming torrents of water. Some of the finest engineering work in the world has been done in these mountain regions. We publish in this issue engravings, showing some "flume engineering," the novelty of which, we feel satisfied, will be as sensibly appreciated by our readers as by ourselves.

Although we had frequently heard of this particular piece of work, we had not seen anything that would enable us to form an opinion as to its merits until quite recently, when we were shown photographs of it, which showed plainly many of the difficulties met with and overcome in its construction.

The engravings we have had made are excellent reproductions of the photographs referred to, and give a very distinct idea of the manner in which the work was done, and a general view of it after completion.

It is located at the head of what is now called "Bracket Cañon," in Butte county, in this State (about ten miles from Oroville), and is a part of the fluming on the Miocene Mining Company's ditch. It was designed by and constructed under the immediate supervision of Mr. Wm. H. Bellows, superintendent of construction of that company's ditch and flumes. In order to escape the necessity of a trestle-work 186 feet high, as designed by the engineer who located the line, Mr. Bellows determined to run the line of ditch up the cañon some 200 yards, where it ends against a perpendicular wall of rock 350 feet high. Around this wall the flume was carried on iron brackets set eight feet apart, each bracket capable of sustaining a weight of fourteen and

FIG. 1.—BRACKET FLUME OF MIOCENE MINING COMPANY'S DITCH, BUTTE CO., CAL.

a half tons. The length of this bracketed portion is 486 feet. The flume runs around 118 feet above the bed of the ravine, and from the flume to the top of the cliff above is over 200 feet.

The Oroville *Mercury*, in an article descriptive of the Miocene ditch, speaking of this particular piece of work, says: The man that carried the idea into practical form, from its inception to final completion, is Wm. H. Bellows, the engineer in charge of the work. To him was delegated the task of carrying many hundred feet of flume across an inaccessible gorge, without trestle-work or other support than that which could be given by the perpendicular walls of basalt that stand in fluted columns at the head of the ravine. "What man had done man can do," has often been said; but this particular kind of work had never been done anywhere, and as it was wholly without precedent, the ways and means were left entirely to Mr. Bellows' inventive skill. He was equal to the occasion. From the top of the beetling cliffs above men were swung in ropes, and holes drilled in the side of the basalt walls, that run up in that locality 350 feet as straight as the side of a house. T rails of thirty pound railroad iron were then bent into the form of an L, ten feet being left for the bed of the flume to rest on, two feet rounded off and set into ring-bolts clamped and soldered into the holes into the rock. These iron brackets (from which the cañon derives its name) are eight feet apart, each bracket being capable of sustaining a weight of fourteen and a half tons, and upon them the flume is built. From the uprights at the side of the flume run suspenders, three-quarter inch round iron being used; they also having had holes drilled in the rock for their insertion, and are clamped and soldered securely. The flume, which is four feet wide, inside measurement, and three feet deep, having a capacity of 3,000 inches of water, is a species of work with which every one has an intimate acquaintance, and hence need not be described here. It was thought by many that this piece of fluming was impossible, and at least fraught with such danger as to deter any man or set of men from working there, but not a single accident occurred, except in one case, where the man himself was more careless than his surroundings justified. Combining, as it does, beauty of design and strength of construction, the flume seems at a distance to be suspended in the air, and is an enduring monument to the skill and energy of its projectors. It is believed that this is the only instance of the kind in the history of hydraulic mining where a flume is carried around a perpendicular cliff in the manner above described.

The engraving shown above represents a portion of the bracketed flume, by which the construction can be understood. The engraving opposite gives a general view of the bracketed flume where it passes around the vertical wall. This also shows where a stream from above passes over the flume. An "apron" has been put up at the point, to keep any of the water from the fall coming into the flume. The trestle work shown is eighty-six feet high; but in the line of this ditch, a trestle 136 feet high has been built. There is one place on the ditch where there is a piece of trestle-work 1,088 feet long and eighty feet high—said to be the handsomest piece of work of the kind in the State. The ditch and flume itself is eighty-three and a half miles long. The flume has a carrying capacity of 3, 00 miners' inches.—*Min. and Sci. Press.*

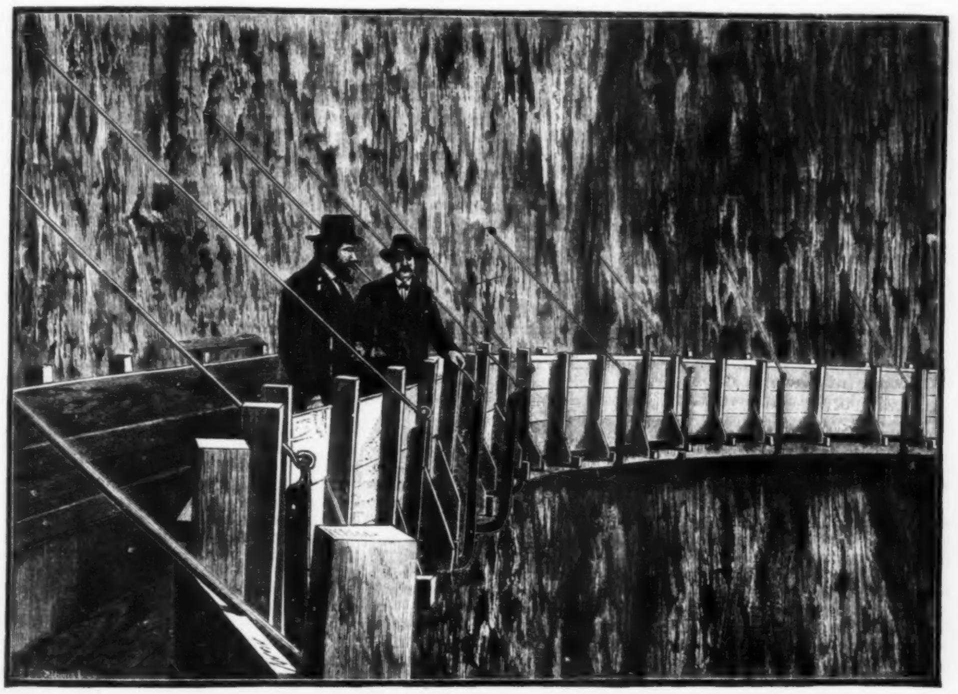


FIG. 2.—METHOD OF HANGING FLUME TO CLIFF BY IRON BRACKETS.

SUGGESTIONS FOR CONSTRUCTING FIRE-PROOF BUILDINGS.

By ISAAC P. NOYES, Architect, Washington, D. C.

SOME system is very much needed by which, without greatly enhancing the cost, our buildings may be better secured against fire. We here offer some hints, but do not propose to make an absolute fire-proof building in the sense of its being so secure against such an agent as to be indestructible; for that, at this age of the world, would be impossible; but we propose an arrangement by which, at a slight cost, a building may be rendered more fit to resist this devouring element. Neither do we claim for our method that it is the only one that will give good results; we simply offer it as *one* way in which fire may be prevented from accomplishing such fearful destruction as it sometimes does in a thickly settled locality.

The first thing in order to have a building in any way fire-proof is to see that it is built of such material as will best resist fire; the next, to see that it is properly built. Experience thus far has proved brick to be the best material with which to construct such a building. It is not as elegant as stone, yet, if treated rightly, very grand and imposing structures may be built of it. The parts are small, but if they are properly massed they may be worked up in a most imposing manner. The way in which the interior of the majority of our best buildings are made fire-proof is by forming the floors of rolled iron girders, carrying brick arches; this, though, is quite expensive, and few can afford it. But even such buildings have been devoured in large conflagrations almost as readily as those of more common construction. Few of the better class of buildings, in ordinary times, catch fire from within and extend the fire to other buildings. Those which are the more apt to be the means of extending fire are generally of the cheapest class, probably fine looking from without, but within devised in such a manner as to invite the rapid spread of flames.

Water is the great element used against fire. Steam, under certain circumstances, is one of the best protections; so much so, that we now have first-class safes constructed on the principle of holding in reserve an ample amount of water to generate steam sufficient to act as a protection against fire. Carbonic acid gas is also used to a certain extent, but water is the most general and common agent in use, and this we propose to use by having a supply of it so stored as to be readily made available, and to act somewhat in the manner of steam, thereby keeping the temperature of the exposed parts so reduced as to prevent them from becoming heated enough to serve as a conductor to the more inflammable material within or beyond them.

We would build of brick, after the ordinary styles, using care not to introduce wood in such a careless manner as to neutralize the benefits of the system herein proposed. In the process of construction, we would leave a slight air-space, say three or four inches, between our building and those on either side; or, where parties build together, make the party walls hollow; this could be accomplished without showing any open space in front. For the interior supports, we would use hollow cast iron posts, notwithstanding that in some of the great fires they were found to be insecure when exposed to a powerful heat, but we would make some slight changes in them, as will herein be described.

In this plan it would make no difference whether a French roof were adopted or not, so long as it was properly constructed. By the way, no French roof should be allowed on any building, and particularly on a high one, in a thickly settled locality, unless it were constructed of iron, or in some way made fire-proof. We would propose gas pipe for the purpose, as being both light and strong, and as possessing the quality of being easily worked into any desired shape. Again, by the way, we would note the fact that a French roof, in reality, forms more of the side of a building than of the roof proper, the greater portion of it being flat, as the majority of other roofs.

In order to carry out our method, we would construct what is ordinarily termed a *flat* roof, with the addition of sides, as though we were forming a tank; these sides to be about a foot high, and suitably strong for the purpose. They may be constructed in a number of ways. The covering to the roof to be of tin, and water-tight, and the roof itself capable of supporting, when required, the weight of an amount of water to the depth of about one foot. Where the roof is long, it would be well to have it divided by cross partitions into bays or sections, from front to rear, otherwise, as water will find its level, if there were a foot of water at the highest portion of the roof, at the lowest point there might be three or four feet, which, for ordinary buildings, might be too much weight. These cross divisions would necessitate extra conductors, yet that would be a small item and could be easily managed. If introduced they should be slightly diagonal, and not straight across the roof, as that would be the most ready way to cause the water, in ordinary times, to run to a common point, the necessity for which would be readily understood by the practical man.

The tank need not be kept filled all the time, unless so desired, but it should be so connected with a water supply, by hydrants or force pumps, that it could readily be filled at very short notice; and during the raging of a fire in the immediate vicinity, it should be kept full enough to overflow in small quantities over the sides of the building, and, if desirable, into the hollow iron posts. The ordinary conductor pipes should be arranged with a suitable turn-off valve, so that when the tank was filled the water would not be allowed to run off too freely, but be held in reserve for service. Up and down the sides of the building, in the side walls as well as in the front and rear, there should be arranged small troughs, which, in the design for the front (and rear if desirable), could easily be disguised as belt-courses, introduced into window-heads, etc.; also within the iron posts there should be places to catch and hold small quantities of water. These troughs, as well as the gutters, would hold the water, and the heat, if near at hand and powerful enough under ordinary circumstances to injure the building, would, where there was a constant supply of water, generate steam from it in sufficient quantity to enshroud the whole building, and afford it superior and ample protection.

In an iron front, this arrangement could easily be carried out, and at fires in the immediate vicinity of iron structures there would no longer be that peculiar danger which firemen realize to be so great. This method, it will be seen, would do away with shingle and slate roofs in commercial and block buildings, where it might most probably be introduced, though slate might still be used on the steeper portions of roofs where there would be a flat above for containing the tank arrangement.

In regard to churches and similar structures with high wooden roofs, they must either be built differently, be more isolated, or have fire proof bulkheads built near them, else suffer the consequences of being built of inflammable material.

If all cannot afford to build in the manner described, it would be well for the municipal authorities of a city, in particularly inviting localities, to assist in building fire-proof bulkheads, in the manner herein described, with their roofs so constructed as to be readily converted into a tank that should be abundantly supplied with water. Such bulkheads, in the presence of a large fire, would convert into an enormous steam generating institution, that would form a barrier that would arrest the flames and confine them within certain areas. These bulkheads need not be worthless space but be combined with some private enterprise; the city authorities, for the better protection of the city, allowing certain parties some bonus for thus making their building answer a double purpose, and, in addition to its private character, becoming a great public blessing. We think that a comparatively few such structures, judiciously distributed throughout a large city, would prevent such disastrous fires as those that have within the past few years occurred in some of our larger cities.

SIR W. ARMSTRONG ON NATIONAL DEFENSE.

AT a recent meeting of the Institution of Civil Engineers, London, Sir W. G. Armstrong, C.B., F.R.S., delivered an inaugural address as president.

He observed that it had been the practice of his predecessors in the chair to select topics for their address that had reference to branches of engineering which operated to increase the productiveness of human industry, and there were many who would contend that all engineering efforts ought to center upon that object. It might be fully admitted that the general amelioration of the material condition of the world was the noblest object of engineering science; and if men and nations ceased to be bellicose and rapacious, such would naturally be the direction which all engineering practice would take; but this was a world of contention, where no individual state could insure its independence, and carry on its industrial occupations in safety, without protecting itself against the possible aggression of its neighbors. Thus it was that the science of the engineer was invoked for the purposes of war as well as for those of peace; and it was probable that the engineering element would in future enter more and more largely into the operations of war, until the issue would be chiefly dependent upon the superiority of mechanical resource displayed by one or other of the contending parties. There was no country in the world less disposed to be aggressive than our own, but there was none so likely to incite the greed of an assailant, or so vulnerable in relation to its commerce. War indemnities had degenerated into mere exactions proportioned to the wealth of the vanquished; and England, being the richest of nations, offered the highest premium for successful attack. As to commerce, England had more than one-half of the ocean carrying trade of the whole world in her hand, and her ships, swarming over every sea and conveying merchandise of enormous value, would, in the event of war, invite the depredation of hostile cruisers. We had seen in recent years what ravages a single-armed ship could inflict upon a mercantile navy incomparably smaller than our own, and, in our case, it was not only property, but indispensable food that was at stake. The ever-increasing population of Great Britain had already far outgrown its internal means of support, while the increasing cheapness of imported food so discouraged native agriculture, that we might expect our future dependence upon foreign supply to increase even more rapidly than our population. This was not the occasion to discuss either moral questions affecting war, or political questions concerning free trade. We had the stern fact before us that national defense was in our case peculiarly a necessity, and the question how it could best be effected, from an engineer's point of view, was a legitimate subject for this address.

England must always be chiefly dependent for security upon her naval power, but we could not hope that she would ever again be so dominant at sea as before the introduction of steam navigation. So long as naval superiority depended upon seamanship and an unlimited supply of sailors, no nation or combination of nations could compete with us; but as soon as it became established that fighting ships could be maneuvered with more certainty and precision by the power of steam than by the power of wind, a revolution began which had gradually made naval warfare a matter of engineering rather than of seamanship.

The introduction of rifled ordnance and percussion shells was the second step in this revolution, and had the effect of condemning as useless the whole fleet of wooden ships with which all our victories had been won, and which were the pride of the nation. Then commenced that contest between guns and armor which had gone on to this day, and had not yet been decided. Nor would it, in all probability, ever be decided, seeing what an *ignis fatuus* finality was.

The most recent stage of this revolution was that marked by the introduction of torpedoes, against which our ponderous ironclads were no more secure than ships of thinnest iron. These constantly-changing phases of attack and defense had placed our naval authorities under extreme difficulty in deciding upon questions of ships and armament. To stand still was impossible, while to act upon uncertain data was sure to lead to mistake. The necessary conse

quence had been that types and patterns of ships had been continually changing, and vessels, costing vast sums of money, had become nearly obsolete almost as soon as made. We could not wonder that, so long as invulnerability was conceived to be attainable, great sacrifice should be made for its accomplishment; but with our present knowledge, which it would be unfair to apply to a criticism of the past, we might feel assured that invulnerability was a chimera. Not only did we see that armor was unavailing against torpedo attack and ramming, but we were justified in concluding that every attempt to increase resistance to projectiles would be quickly followed by a corresponding increase in the power of artillery. Our early ironclads, like the Warrior, were plated all over with armor four and a half inches thick—a thickness which could not be pierced by field-pieces. To resist the most powerful guns now afloat, armor of at least two feet in thickness was required; and in order to reconcile the constantly increasing thickness with the weight which the ship was capable of carrying, it had been necessary to restrict the area of armored surface to ever narrowing limits, leaving a large portion of the ship without protection. In those magnificent and tremendous vessels which the Italians were now building, the armor would be withdrawn from every part except the battery, where guns of one hundred tons would be placed, and where the armor would be confined to a narrow belt of great thickness. Everything of importance that projectiles could destroy would be kept below water-level, and, so far as artillery fire was concerned, the ships would be secured against sinking by means of an under-water deck and ample division into compartments. Armor therefore seemed gradually contracting to the vanishing point; but, until it actually disappeared, it was probable that no better application of it could be made than had been decided upon by the acute and enterprising naval authorities of Italy for the great ships they were now constructing.

The dread of the terrible effects of the fragments of shells bursting amidst a crowded crew, and the apprehension that the smoke from the explosion, when it occurred between decks, would paralyze the service of the guns, had conduced more than anything else to the adoption of armor. Methods of avoiding or lessening these dangers, otherwise than by the use of armor, had been little considered; yet the alarming aspect of the case was greatly altered when we reflected that, by the application of mechanical power, to do what had hitherto been done by a multitude of hands the exposure of a crowded crew could be avoided, and also that the guns might all be mounted on an open deck, where the smoke from shells would speedily clear away.

As to the comparative liability of an ironclad and an unarmored ship to be sunk by projectiles, there was much less difference between them than was generally supposed; because the unarmored ship, though freely penetrable, might be so constructed that the entrance of water by perforation would not extensively flood the ship, unless it took place at a great number of critical places. Indeed, by introducing an underwater deck, with divisional spaces, and by the partial application of cork, as in the Inflexible, for displacing influent water, and thereby preserving stability, and also by a proper distribution of coal for the same purpose, an unarmored ship might be rendered almost incapable of being sunk; and it was rather surprising that so little attention had been directed to the attainment of that object.

It was not too much to say that, for the cost of one ironclad, we could have three unarmored ships of far higher speed and carrying collectively three armaments, each equal to that of the armored vessel. It might be asked, Which would be the better investment? If it were imagined that the three were matched in combat against the one, it would be perceived that, in addition to their numerical superiority, the former would possess many advantages. Being smaller, they would be more difficult to hit. Being swifter, they could choose their positions, and be free to attack or retreat at pleasure. Being more nimble in turning, they would be better adapted both for ramming and for evading the ram of their adversary. Finally, the conditions of superior speed and agility would favor their use of torpedoes and submarine projectiles; although it was a question whether, for the sake of a much-needed simplification, it would not be better to confine that species of attack to separate vessels specially constructed for that one particular purpose. Even if the utmost advantage she could possess were conceded to the ironclad, viz., that of being impenetrable by the guns of her opponents—she could not prevail in a contest of three against one, unless, by the use of securely-protected artillery, she could keep her assailants at bay, and gradually destroy them by her fire if they persisted in their attack. Such might be the issue if the allied vessels had nothing but guns to oppose to guns; but they would naturally, under such circumstances, place their men below, out of the reach of projectiles, and then attack with their rams or torpedoes. With the crew in safety, it was scarcely possible that unarmored vessels, with under-water decks and all their machinery beneath, should suffer any disabling injury by being pierced in a few places by either shot or shell. But, take the much more probable alternative of the armored vessel being penetrable by the guns which would be used against her. In that case her enemies might elect to make the contest one of artillery. On their part, armor piercing projectiles would be used which, on penetrating the thick sides of the ironclad, would carry inboard a mass of broken material far larger in quantity than the fragments of the shells with which they would be assailed, and quite as destructive in effect.

The ironclad would have to sustain the converging fire of three ships, each carrying the same armament as her own, and her swift and nimble adversaries would steam round and round her, directing their fire on the most vulnerable points, and ever ready to seize a favorable moment to dash in and finish the contest by ramming. In either case, therefore, the ironclad would be overmatched by a combination of unarmored vessels representing the same pecuniary value. Without entering into technical questions concerning fleet-fighting, it seemed reasonable to believe that the result would be the same if the number engaged on each side were proportionately multiplied. Inferiority of speed and of number would still give the choice of position, and secure the advantage of converging fire; besides which, the greater power of division and of concentration must always belong to the more numerous fleet. But, if ironclads were not needed for the purpose of opposing ironclads, it was difficult to see for what purpose they were wanted at all. For every other kind of service, a numerous fleet of smaller and swifter vessels, unencumbered with armor, would clearly be preferable. To protect our commerce, to guard our extensive seaboard against invading flotillas, to lend naval assistance to our colonies in case of need, and generally to maintain our supremacy at sea, we required a far more numerous navy than we possessed or could afford to possess unless we vastly reduced our expenditure on individual ships, and to do this we must dispense with armor.

It might, perhaps, be rash entirely to abandon armor so long as other nations continued to use it, because nothing but the experience of an actual war would remove all question as to its possible utility; but, considering the indisputable value of a numerous fleet of swift and powerfully-armed ships, built with a view of obtaining the maximum amount of unarmored defense, and considering that such vessels, unlike armor-clads, could never grow much out of date, it did seem to be expedient that the chief expenditure of this country should be upon ships of that description. Lightness should be the special aim in the construction of such vessels. Steel plates should be used for the hulls, and guns and engines should be of the least possible weight consistent with the necessary power. Every ton of weight saved would enable higher speed to be attained, and there was probably no quality in a fighting ship which would so much develop in importance as that of swiftness. Messrs. Thornycroft have led the way in showing what extraordinary speed could be realized in diminutive vessels, by reducing to the utmost the weight of every part of the structure and its contents; and, although we could not expect to attain proportionate speed by the same method in ocean-going ships of war, yet there could be no question that we might have far swifter ships than at present if lightness were made the principal object, instead of the prevalent practice of loading ships with cumbrous armor, in the vain hope of rendering them invulnerable. Light unarmored ships, designed by Mr. George Rendel, had lately been built in this country for foreign powers, which, with a displacement of only 1,300 tons, had attained a speed of 16 knots an hour. They carried coal for steaming 4,000 miles, and had already actually steamed 3,500 miles without replenishing. They were each armed with 10 in. new type guns, which had nearly an all-round fire, and were capable of piercing 18 in. of iron armor; and with four 40 pounders on the broadsides. It was a very serious question what could be done in the event of a number of such vessels as these being let loose upon our commerce. At present there was not a single ship in the British navy carrying an armament competent to engage them, that could overtake them in pursuit, or evade their attack when prudence dictated a retreat. Confidence was often expressed in our mercantile marine being capable of furnishing, on an emergency, a supply of vessels fit to be converted into cruisers; but where were there to be found, amongst trading or passenger steamers, vessels possessing a speed of 16 knots, with engines and boilers below water-level, and having an under-water deck to save them from sinking when penetrated by projectiles at or below the water-line? From his own experience he knew how difficult it was to adapt mercantile vessels to the purposes of war, and how unsatisfactory they were when the best had been made of them. It was alarming to think how unprepared we were to repress the ravages which even a small number of swift marauding vessels, properly constructed and armed for their purpose, could inflict upon the enormous property we had at all times afloat, and how little we could hope to clear the sea of such destructive enemies, by cruisers improvised out of ready-made steamers destitute of all the conditions necessary to render them efficient for such a service. It must ever be borne in mind that it was not merely the loss of property and interruption of trade that we had to fear, but also the interception of food supplies; and that the more our population increased and our agriculture declined, the more terribly effective for reducing us to submission would be the stoppage of those supplies.

The President then adverted to harbor defense. He pointed out that many of our iron-clad forts had already outlived the stage of artillery progress for which they were adapted. He expressed his opinion as to the best method of rendering large guns effective in shore batteries. He dwelt upon the value of gunboats, considered as floating gun-carriages, and used in combination with torpedo craft and submarine mines; all of which, he suggested, might be committed to the management of trained naval and engineer volunteers resident on the spot.

He said it would be a grand development of the volunteer movement, of which this country was so justly proud, if it were thus to be extended to harbor defense; and he was informed that, so far as the use of submerged torpedoes was concerned, a project of intrusting their employment to a corps of volunteer engineers was already under consideration. The superior education and intelligence of the class from which our volunteers were mostly supplied would especially fit them for the discharge of duties involving skill and discretion, such as would be required in the handling of electrical apparatus, and we might be sure that, wherever dash was needed in the use of torpedo boats, there would be no lack of that quality among volunteers in the hour of trial.

On the subject of artillery, he described the progress of gun manufacture since the introduction of rifled ordnance, prior to which a gun was simply a tube of cast iron or bronze closed at one end. He also discussed the question, what, under the present conditions and prospects of steel manufacture, should be our practice as to the use of that material for artillery purposes. He was then led to speak of a system of construction which had not passed through the experimental stage, but which, from the results it had already given, promised to attain a wide application. He referred to that system in which the coils surrounding the central tube consisted of steel wire, or ribbons of steel, wound spirally upon the tube. To those who objected to welded coil tubes on the ground of supposed deficiency of longitudinal strength, this mode of construction must appear especially faulty, inasmuch as lateral adhesion, instead of being, as contended, merely deficient, was altogether absent, while, to those who advocated the present coil system, this variety must commend itself as affording the greatest possible amount of circumferential strength that could be realized from the material employed. Steel in the form of wire or drawn ribbon possessed far greater tenacity, and also greater toughness, than in any other condition, and in applying it to guns there was perfect command of the tension with which each layer was laid on. He then alluded to the labor of those who had worked in this direction, and referred to a 6 in. breechloading gun of this construction made at Elswick, and tried in the beginning of 1880. He stated that the charges used with it were large beyond precedent, and the energies developed proportionately high. Being satisfied with the results obtained with this gun, a second one of larger dimensions had been commenced, and was now finished. Its caliber was 26 centimeters, or about $10\frac{1}{4}$ in. Its length was 29 calibers, and its weight was 21 tons. In the previous gun he depended for end strength upon the thickness of barrel only; but in the new one, layers of longitudinal ribbons were interposed between the coils, in the proportion of one longitudinal layer to four circular layers. The longitudinals were secured to the trunnion ring at one end and to a breech-ring at the other, and were in themselves calculated as sufficient to resist the end strain on the breech, independently of the strength afforded by the tube. The whole was incased in hoops shrunk upon the exterior of the coil, for the treble purpose of protection from injury, of preventing slipping in the event of the failure of an external strand, and of adding to the strength of the gun. This gun has already been tried, and had given results which, in relation to its weight, were unexampled, except by its six inch predecessor. Various attempts had also been made abroad to reduce this system to practice, and it was understood that the French were at present engaged in making experimental guns upon the same general principle. With regard to the ribbon form of section, he preferred it to a square section of equal area, as being more favorable for bending over a cylinder, but any rectangular form was better than round wire, on account of the flat bedding surfaces it afforded.

He then discussed the subject of breech-loading and muzzle loading, and the various forms of rifling. He also described the many changes that had been found necessary in the form and manufacture of powder for heavy ordnance, and the difficulties which still remained to be overcome.

As to the mounting of guns in forts and ships, he remarked that the difficulties of the problem were much greater than was commonly supposed. It was certain that machinery could be no longer dispensed with for working the guns, and that engine power must be used to economize labor and avoid exposure of the men. In the days of cast-iron smooth bores, the heaviest naval gun weighed 95 cwt., and it was deemed impracticable to exceed that limit in a ship. At the present time, the heaviest naval gun in the British service was 80 tons, and guns of 100 tons were carried in Italian ships. Instead of projectiles weighing as a maximum 94 lb. and charges of 16 lb., we had now to handle projectiles of 1,500 lb. and charges of 450 lb.; and to keep pace with foreign navies those limits of weight must be greatly exceeded. Even if it were possible to deal with guns and ammunition of such weights by manual labor, the multitude of men required for the purpose would be greater than could find standing room at the guns. Up to a certain point hand power might be so aided by machinery, as to enable larger guns to be worked by men than was formerly deemed possible; but the mechanism required to render hand power available was quite as liable to be disabled by an enemy's fire as that which would be applied in connection with engine power. There was, therefore, no reason in this respect for employing a numerous gun crew in preference to inanimate power. Automatic methods of varying out the gun, by which the gun was lifted in recoiling by slides or radius bars and recovered its position by gravitation, might in many cases be advantageously used to save labor, but in a ship the varying inclination of the deck interfered with uniformity of action. The upward motion of the gun also involved the objection of a higher port, and it added greatly to the downward shock, which became very severe on the deck where the guns were large and were fired at considerable elevation with such heavy charges as were now usual. Steam power, acting through the medium of hydraulic pressure, was already largely applied in recent ships for effecting all the operations of working the guns, and where such power was used there was nothing to gain by automatic action for returning the gun into firing position. In considering these various mechanical arrangements now applicable to naval warfare, we perceived the growth of the engineering element in our ships of war, and the importance of mechanical, as well as nautical, acquirements on the part of the officers, as also, in a less degree, on that of the men. Breechloading guns, carriages fitted with all modern appliances, shot and powder lifts, mechanical rammers and torpedo apparatus, all combined with steam or hydraulic machinery, or with both, constituted mechanisms requiring to be supervised by officers qualified as engineers, and to be handled by men trained in the use of machinery.

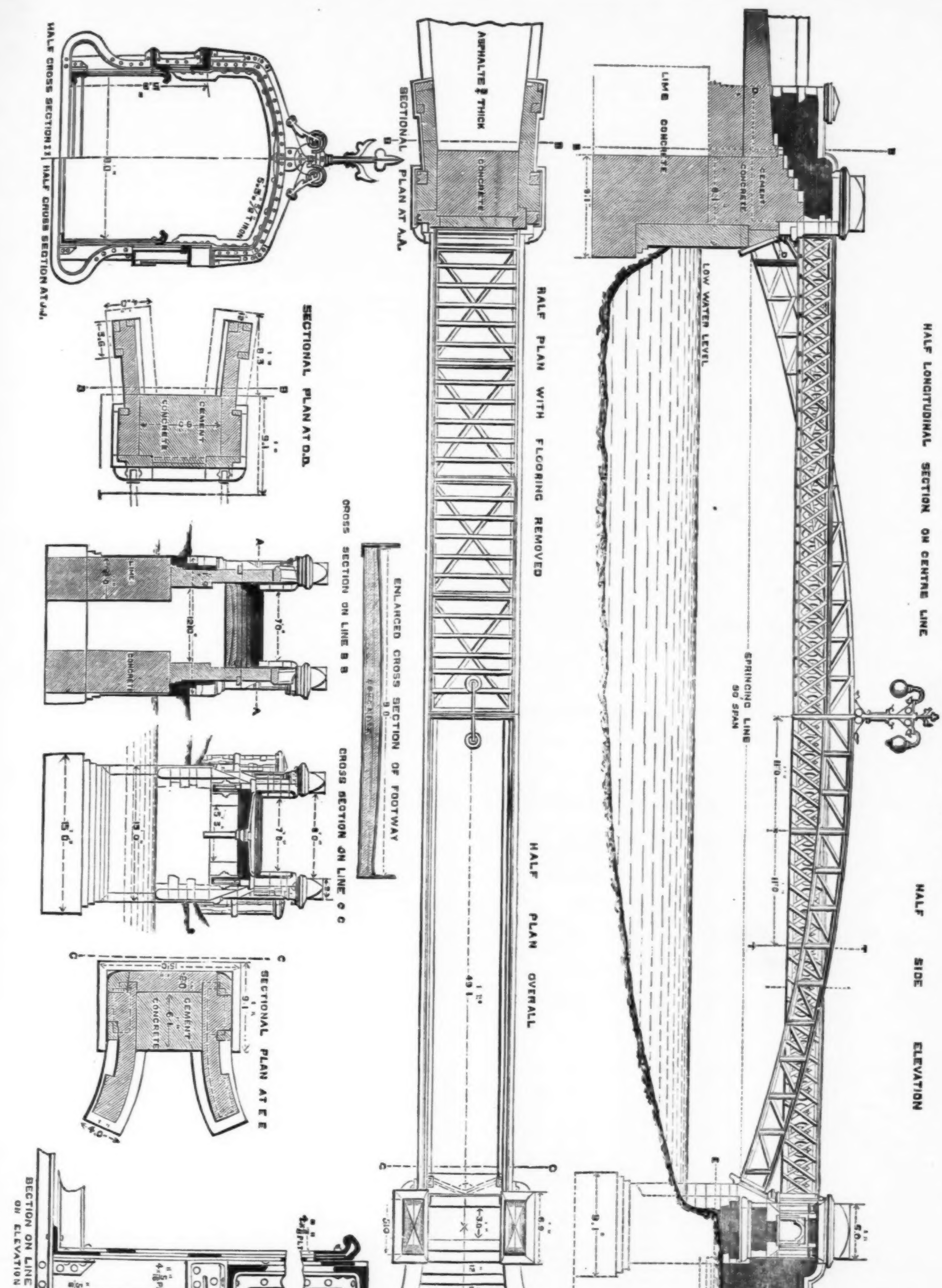
Before drawing to a conclusion he would advert to a subject of great national importance. Our navy was at present armed with guns which could not be expected to contend successfully with the best modern guns that could be used against them. Happily, most of the older ships of foreign powers were in the same predicament; but all their new vessels, and some of their older ones, were being armed with artillery which, weight for weight, was far superior in power to that of our navy. Our service guns had simply been overtaken in that rapid progress of artillery which had been going on for the last eight or ten years; and it might be doubted whether any partial remodeling during that period would have averted the present need of rearmament; while it would certainly have involved great sacrifice and confusion of ammunition and stores. But a new departure could not longer be delayed. An irresistible demand had arisen for breechloading guns, and it was imperative to combine, with the introduction of that system, such other modifications of construction as would realize the increase of power which we now knew to be attainable.

It might, however, be asked what better prospects of finality there were now then we had ten years ago. As to absolute finality, it would probably never be reached, but the country might take some comfort in the reflection that every stage of progress narrowed the field for further development. There was already no substantial room for improvement in the accuracy of guns; and as to power, we were nearly approaching the limit at which severity of recoil and extravagant length of gun would prohibit further advance. We might go on building larger guns almost without limit, though he doubted the policy of so doing, but mere increase of size did not revolutionize system. There seemed, therefore, to be more hope of permanency now than at any former period; but whether this were so or not, we could not, with danger, remain passive.

What, then, should our government do in regard to the great work of rearming the fleet? He took it for granted that all new ships would be armed with the best guns that could now be made, and that the more important of the older vessels would speedily receive the same advantage; but beyond this, so long as experience of novelties was deficient, it was a case for cautious procedure. In the mean time, no expense should be spared in judicious experiments, seeing that the expense of experiments was trifling in comparison with that of mistakes. Above all, the government should pursue such a course as would bring into full play the abundant engineering resources of this highly mechanical country, for increasing the efficacy of our national defenses.

THE WELLAND RIVER FOOT BRIDGE.

IN our last week's SUPPLEMENT (No. 321), we gave a description of this structure, from the *Engineer*, with a few sketches and description. We now complete the series of illustrations, and refer the reader to our last issue, page 5114, for a description of the work.



FOOT BRIDGE OVER THE RIVER WELLAND, AT STAMFORD.

MR. J. B. EVERARD, C.E., LEICESTER, ENGINEER.

NEW DOCKS AT MILFORD.

POSSESSING so many natural advantages as Milford Haven does for an extensive harbor, it is somewhat strange that up to a comparatively recent date no attempt was made to utilize it for that purpose. About five years ago a private company was formed, with a capital of £530,000, for the purpose of constructing extensive docks, but progress was very slow, until Messrs. S. Lake & Co., of Victoria street, obtained the contract, in June, 1879. Since then this enterprising firm has endeavored in every possible way to satisfactorily complete the docks, and prepare the way for a vast commercial undertaking, which, in all probability, will prove remunerative to the promoters and be of inestimable benefit to the community. It is impossible to give an adequate idea of the magnitude of the work now being carried out at Milford, and which is fast approaching completion, but some conception of the area covered and the amount of constructive work gone through is attempted in the following remarks:

The docks themselves were designed by Sir. E. J. Reed, the late Chief Constructor of the Navy, specially for the accommodation of vessels of the largest tonnage, such as ironclads and the new mail steamers to America. When the Great Eastern was launched she was expected to be the type of a fleet of similar monsters, and though that anticipation was not fulfilled, very great advances have, as every one knows, been made both in the size and in the speed of ocean steamers. It is not probable that vessels much larger than, say the Servia, will be built for commercial purposes; but, taking the Servia as a fair example of the steamship of the future, it was necessary to provide docks at Milford capable of receiving such giants.

Broadly speaking, the dock schemes may be described as the reclamation of Hubberston Pill, one of the side creeks debouching into Milford Haven, through the center of which runs an insignificant stream of fresh water, the feeble representative of the powerful torrent, which, in some long past geological epoch, must have cut out of the red sandstone the deep precipitous gully now covered by beds of clay, mud, and silt, which in some places exceed seventy feet in depth. These peculiar conditions, combined with the fact that the old red sandstone beds were much fissured and highly pervious to water, rendered the adoption of the ordinary system of dock construction, viz : the throwing of a coffer dam, whether of timber or earth, across the entrance of the site, quite inadmissible. The more costly and difficult mode of constructing by tide work was, therefore, of necessity resorted to in order to expedite the rate of progress, and at the same time secure thoroughly substantial foundations for the walls.

The contractors have introduced and applied some interesting engineering devices. The whole of the dock and lock walls are built of Portland cement concrete, made of the best quality Portland cement and local gravel mixed with local limestone and sandstone; the walls are faced, wherever requisite, with a superior quality of mountain limestone, and will be coped with the same material. Two principal methods of construction have been employed in building the walls wherever the rock is to be found at a moderate depth below the old surface, and also in places where special strength and stability are requisite; as, for instance, for the foundations of the quoins at the dock entrances the walls have been carried down and founded on the rock throughout their length. Secondly, in places where the rock was only to be found at a very great depth, and where the walls will not be subjected to any special or extra strain, they have been built upon a series of concrete tubes of great size and solidity. This is an adaptation of the old Indian well system. The tubes are sunk through soft strata by the simple process of excavating the mud from the exterior, and so compelling them to descend by their own weight. When a firm foundation is reached the rock is leveled so as to form an even base, and the interior of the cylinder is filled up with concrete, thus forming a solid pier on which to rest the walls.

The surface alluvium of the pile, although nearly approaching clay in character, is, when once disturbed and subjected to the tidal action, very unstable and shifty, and much difficulty was experienced in efficiently timbering the foundation. To obviate this the contractors devised and introduced their iron caissons, which are set up on the site of the wall, one in front and one at the back. The ends are connected by cross planking, which are bolted to the caissons and the joints properly calked, thus forming a rigid water-tight box. These caissons are usually carried down about ten feet below the surface. When the wall is complete the caissons are easily lifted by being slung to a barge on the rising tide.

As may easily be imagined, the pumping arrangements in connection with this form an important feature of the works. The pulsometer pumps, which throw each from eight hundred to one thousand gallons a minute, have exclusively been used, and their efficiency was no less a matter of remark than their curious construction, which may have suggested to an anatomist the form and action of a pair of lungs.

The total available dock area, 60 acres; lock 500 feet long by 70 feet wide; graving dock, which can also be used as a lock or wet dock, 710 feet long, 96 feet wide; small graving dock, 270 feet long, 46 feet wide; depth over sills, high water spring tides, 36 feet, and at high water neaps, 27 feet; depth of water in docks, 28 feet.

The entire town of Milford, as well as the small town of Hakin, originally belonged to Colonel Greville, and became subsequently the property of the National Provident Institution, who have leased it for nine hundred and ninety-nine years to the present owners. The property includes, besides these two towns, the foreshore for a distance of a mile and a half, and all market rights and rights of levying tolls on passing vessels. The estate extends over about six hundred acres.

DETAILED COST OF A LOCOMOTIVE.

THE table below gives the cost of an ordinary 8-wheel passenger locomotive (having a wagon-top boiler) which was built in 1879 in the shops of one of the trunk lines, to haul the road's fastest passenger train. Its efficient service during the two years since, in which it has made a mileage of nearly 100 000 miles, has demonstrated the good workmanship of its construction.

The columns, number 1 to 6, show the number of hours of work done for wages at the different rates per day of ten hours as follows, to wit:

Column 1; wages at 50 and 75 cents;
Column 2; at $1.00, $1.12, $1.20, $1.30, and $1.45;
Column 3; at $1.50, 1.60, $1.65, $1.70, $1.75, and $1.90;
Column 4; at $2.10, $2.15, $2 20, 2.30, and $2.40;
Column 5; at $2.50, $2.70, and $2.90; and
Column 6; at $3.00, $3.30, $3.35, $3.50, and 3.65.

The cost of "erecting" is $468.21, and includes 1,857 hours at an average of 25·2 cents per hour. This is distributed in the table, giving to each specification its appropriate part.

The average rate per pound given is cents and tenths of a cent, and is computed upon the rough weight of the material used in each specification. The total cost per pound of the finish weight of the engine complete (which is about 80,000 lb. empty) is—for labor, 2.9 cents; material, 6.1; and total for both, 9 cents.

The slabs of the frame, as received from another shop, weighed 4,188 lb., and are charged in material at $519·73, which is 12.4 cent. per pound for labor and material.—*Nat. Car Builder.*

DETAILED COST OF A PASSENGER LOCOMOTIVE.

SPECIFICATIONS. Name.	No.	LABOR. See explanation. 1	2.	3.	4.	5.	6.	Total hours	Average rate.	Total cost.	Cost per lb	MATERIAL. Rough weight, lbs.	Total cost.	Cost per lb	MATERIAL AND LABOR. Total cost.	Cost per lb
Boiler	1	35	71	528	726	978	104	2,442	21.6	$527.33	2.5	21,085	$1,322.37	6.3	$1,849.70	8.8
Grate	2	5		15		30		50	21.0	10.49	1.5	710	14.73	2.1	25.22	3.6
Frame	3	11	22	135	253	67		488	21.5	105.17	2.2	4,866	530.44	10.9	635.61	13.1
Cylinders with bolts and studs	4		30	55	105	365		555	23.7	131.56	2.2	5,896	307.60	5.2	439.16	7.4
Cylinder heads and casing	5			2	46	37		85	24.4	20.73	1.7	1,219	25.60	2.1	46.33	3.8
Steam chests, covers, bolts and studs	6	5	11	7		54		77	21.5	16.55	2.0	819	19.40	2.4	35.95	4.4
Guides	7		15	30	111	192		348	21.2	73.87	7.4	902	61.98	6.2	135.85	13.6
Guide yokes	8			51	35	33		118	20.9	24.63	4.2	585	85.25	14.6	109.88	18.8
Cross heads	9		22		58	21		101	21.3	21.44	6.3	338	7.36	2.2	28.80	8.5
Pistons and rods	10	6	10	19	55	35		125	21.2	26.46	3.3	780	27.70	3.5	54.16	6.8
Slide-valves	11	2			21	15		38	21.5	9.18	4.6	198	4.16	2.1	13.34	6.7
Valve rods	12		1	18	7	26		52	22.0	11.43	10.0	114	1.71	1.5	13.14	11.5
Valve yokes	13		2	15	14	14	10	55	24.0	13.46	12.2	110	3.40	3.1	16.86	15.3
Main and parallel rods	14		31	167	36	474		708	22.5	160.26	12.8	1,250	115.13	9.2	275.39	22.0
Driving wheels, axles and tires	15	1		11	8	139	1	160	24.3	38.82	0.3	15,014	632.38	4.2	671.20	4.5
Driving boxes and cellars	16			24	24	95		143	23.1	33.08	3.9	852	45.88	5.4	78.96	9.3
Equalizers	17		7	67	18	38	37	167	21.3	37.90	8.0	470	7.10	1.5	45.00	9.5
Spring hangers	18			19		38		57	23.2	13.21	8.3	160	3.06	1.9	16.27	10.2
Driving springs	19			24		24		48	26.3	12.11	3.0	405	20.13	5.0	32.24	8.0
Driving spring saddles	20				1			1	17.0	.17	0.1	156	18.72	12.0	18.89	12.1
Pedestal wedges	21	2	1	17	1			21	15.5	3.24	1.5	215	4.49	2.1	7.73	3.6
Pedestal shoes	22			10	1			11	16.0	1.74	1.0	168	3.52	2.1	5.26	3.1
Expansion plates and braces	23	19	2	110	1	153	27	312	21.9	68.20	11.8	579	10.52	1.8	78.72	13.6
Rocker boxes	24		10	8		38		56	23.4	12.92	3.1	424	8.89	2.1	21.81	5.2
Rocker arms	25			7		79		86	25.4	21.88	10.2	215	25.80	12.0	47.68	22.2
Links	26			137	48	222	19	426	25.5	108.68	38.8	280	17.15	6.1	125.83	44.9
Eccentric rods	27			61	1	48		110	21.8	23.94	10.4	230	4.55	2.0	28.49	12.4
Eccentric straps	28			18	5	71		94	23.6	22.21	4.3	515	10.82	2.1	33.03	6.4
Eccentrics	29	3	7	14	8	25		57	21.3	12.02	2.2	548	11.49	2.1	23.51	4.3
Tumbling shaft	30			9	9	67		85	24.2	20.53	9.5	215	3.23	1.5	23.76	11.0
Tumbling shaft and spring boxes	31	5	6	1	3	12		27	19.0	5.12	3.2	161	3.36	2.1	4.48	5.3
Reach rods	32			15		50		65	23.1	15.04	15.5	97	1.94	2.0	16.98	17.5
Reverse lever and spring	33		1	33		88	4	126	23.7	29.06	18.4	158	6.40	4.0	35.46	22.4
Sector	34			3	3	13		19	23.5	4.45	21.2	21	.42	2.0	4.87	23.2
Mud ring and cap	35	6	2	2	4	56		70	22.7	15.90	7.5	212	22.73	10.7	38.63	18.2
Throttle box gland and lever	36	1		5		36		42	24.1	10.13	35.0	29	3.74	13.0	13.87	48.0
Whistle and lever	37			3	1	8		12	23.7	2.84	6.4	44	6.55	15.0	9.39	21.4
Sand box	38	3	5	1	1	65		75	24.0	18.00	4.5	398	11.53	2.9	29.53	7.4
Checks, complete	39			11		38		49	23.0	11.28	6.4	176	20.03	11.4	31.31	17.8
Pop valve, complete	40			3	2	5		10	21.5	2.15	7.2	30	6.95	23.1	9.10	30.3
Dome	41	2		6		39		47	23.7	11.15	1.0	1,149	24.24	2.1	35.39	3.1
Stand pipe	42		1	3	3			7	20.0	1.40	0.7	202	4.24	2.1	5.64	2.8
Dry pipe	43			3	8	80	2	93	24.6	22.87	6.4	359	41.29	11.4	64.16	17.8
Crotch and steam pipes	44			8	10	30		48	23.2	11.20	2.2	491	10.30	2.1	21.50	4.3
Exhaust pipes	45	1		2		1		4	15.0	.60	0.6	95	2.98	3.1	3.58	3.7
Front end of smoke box	46		5		1	13		19	21.9	4.15	0.9	438	9.10	2.1	13.34	3.0
Headlight boards and brackets	47		3	2	1	13		19	22.0	4.18	2.7	158	3.19	2.0	7.37	4.7
Headlight	48												70.00		70.00	
Running board and hand rail brackets	49			38	1	43		82	21.4	17.54	6.1	287	5.74	2.0	23.28	8.1
Jackets and lagging	50				30	40		70	26.9	18.80	2.1	888	29.49	3.3	48.29	5.4
Cylinder casing and lagging	51			2	1	44		47	24.5	11.55	26.3	44	2.64	6.0	14.19	32.3
Smoke stack	52	30	5	11		50	8	104	19.0	19.58	2.9	668	31.18	4.7	50.76	7.6
Cab	53				122	6	151	279	27.4	76.35			36.58		112.93	
Engine truck	54			157	12	87	73	329	22.6	74.49	1.0	7,503	195.92	2.6	270.41	3.6
Tender trucks	55		25	119	26	72		242	22.6	54.70	0.5	11,729	286.87	2.4	341.57	2.9
Tender frame (wood and iron)	56	5		108	68	116		297	21.4	63.44	0.8	7,563	131.64	1.8	195.08	2.6
Tank (steel)	57	7	14	110	143	189	21	484	21.3	103.11	1.8	5,673	309.00	5.5	412.11	7.3
Steam gauge stand	58			6		114		120	24.7	29.67	2.8	106	19.08	1.8	48.75	4.6
Deck casting	59		7	11	8	79		105	24.2	25.43	2.0	1,323	27.75	2.1	53.18	4.1
Driving wheel covers	60	4	4	83		22		113	16.5	18.63	7.2	258	7.23	2.8	25.86	10.0
Number plate	61	1		1	1	2		5	21.8	1.09	4.3	25	2.86	11.5	3.95	15.8
Pilot	62	5	5	27	80	25	8	150	22.6	33.91	2.2	1,571	16.30	1.0	50.21	3.2
Front and back braces	63			50		81		131	21.9	28.68	8.1	353	6.25	1.8	34.93	9.9
Injectors	64												100.00		100.00	
Injector fittings	65			1		82		83	26.3	21.85	10.2	214	13.28	6.2	35.13	16.4
Chafing plate	66	1	1	4		5		11	18.5	2.04	1.9	107	2.24	2.1	4.28	4.0
Total		160	326	2,407	2,120	4,957	489	10,460		$2,353.50		96,947	$4,880.69		$7,241.28	
Averages									22.5		22.6			5.0		7.5

GAS vs. STEAM AS MOTIVE POWER.

WHEN twenty indicated horse-power are required to drive a dynamo-electric machine, which will require least fuel, a gas engine or a steam engine?

Various attempts have been made to answer this question, and hitherto they have all led to the same result, namely, that the gas engine costs more to work it than the steam engine. The latest utterance on the subject is that of Professor Ayrton, who delivered a lecture in French, on the "Economical Use of Gas Engines for the Production of Electricity," during the Electrical Exhibition held last autumn in Paris. Professor Ayrton shows that so long as gas at 3s. per 1,000 cubic feet is used, so long must the steam engine be the cheaper motive power; but he goes on to explain that if a gas manufactured on Dowson's system be used, instead of ordinary coal gas, the result is different, and the gas engine becomes the more economical motor. Professor Ayrton's lecture contains several statements which demand notice, and we are by no means satisfied by his reasoning that the gas engine can, under any circumstances, compete with the steam engine on the basis of fuel consumption alone. But this statement is really not an argument against the use of gas engines, because they possess so many admirable qualities, when used under special conditions, that the cost of fuel becomes of secondary importance; still it is of sufficient importance to claim accurate statement. Now Professor Ayrton begins with a proposition which is true only in a sense, and can be, and often has been, perverted from its true meaning. He states that the steam engine wastes nine-tenths of all the heat evolved during the combustion of the fuel burned to put it in motion. "At present," said Professor Ayrton, "steam engines are chiefly used to drive dynamo machines, but even with the best engines and boilers it is well-known that the fuel consumption is excessive compared with the actual work done. So good an authority as Sir William Armstrong has recently said that with a good condensing engine one-tenth of the whole heat energy of the fuel is realized in useful work, and this is no exaggeration of facts." To those not well acquainted with the subject this statement will appear to mean that the steam engine wastes, as we have said, nine-tenths of all the heat generated; but, as a matter of fact, it does nothing of the kind. The efficiency of any heat engine, no matter what, depends on the limits of temperature, T and t, between which it works, and what we may term its coefficient of useful effect, is found by the well-known formula, $\frac{T-t}{T} = E$, where E is the practical efficiency of the engine. Now, with the steam engine, when well made, E, as determined by practice—that is to say, as measured by the work done—compares very favorably indeed with E as obtained by theory; and the steam engine is not at all a wasteful machine. That it rejects a large quantity of heat is certain, but this heat has been first used in making the working fluid—steam. The loss lies in the fact that the whole, or nearly the whole of this fluid, after being made, is lost; while it is retained very good use indeed is made of it by the best engines, and Professor Ayrton's statement is hardly fair to the steam engine, although it is, no doubt, true in a sense; but the sense is so readily mistaken that Professor Ayrton would have done well to explain in which of the two he used his words. We regret, indeed, to find that throughout he appeared to manifest a spirit of hostility to the steam engine. Thus, for instance, he says: "Engines and boilers of the portable type are those generally used now for electrical purposes, and in a competition in England of several of the best engines of this class the fuel consumption was about 4 lb. per indicated horse-power per hour; but in daily practical work it may be assumed at 6 lb. to 7 lb., more nearly representing the usual fuel consumption. This gives an efficiency of only about one-thirtieth." We do not know to what competition Professor Ayrton refers—the last held in Great Britain was at Cardiff, when Messrs. Clayton and Shuttleworth's engine burned only 2·8 lb. per indicated horse-power per hour—but we do know that Messrs. Fowler, of Leeds, claim that their compound, electric-light engines work with less than 3 lb. of coal per indicated horse-power per hour; and we know that Messrs. Ransomes, Head, Jefferies' engine on the Thames Embankment works up to 42 horse power with but a fraction over 3 lb. per indicated horse-power per hour. In any competition between the gas engine and the steam engine, the latter will have to reckon with a consumption of not more than 3·5 lb. of coal per horse per hour, or about one-half the quantity stated by Professor Ayrton.

The best performance of a gas engine of large power, say 40 horses, is one horse-power indicated for 20 cubic feet of gas. We have only to divide the price of gas per thousand cubic feet by fifty to get at the cost of fuel in this case. Thus, with gas at 3s., the cost is 0·72d.; with gas at 4s. the cost is 0·96d.; with gas at 1s. it is 0·24d., and so on. The price of 3·5 lb. of coal, at 1s. per ton, is 0·01872d.; consequently, with coal at 10s. per ton, the cost in fuel of 1 horse power per hour is 0 1872d.; with coal at 20s. per ton the cost rises to 0·375d., or little more than one-half that of a gas engine worked with gas at 3s. per thousand. It appears to be quite clear, therefore, that so long as ordinary coal gas is used, there does not appear to be the least chance that the

gas engine can rival the steam engine, and Professor Ayrton ought to see that the reason why is just the same as that which leads to the species of so-called waste with which be charges the steam engine. It is the cost of the working fluid with which we have to contend in each case. An explosive mixture of coal-gas is more expensive than the quantity of steam required to develop the same power, and the gas is as much wasted and lost as is the steam. That, however, the gas engine makes better use of its working fluid than the steam engine does of its working fluid is not impossible. All future attempts at the improvement of the gas engine, apart, of course, from structural ameliorations, must be directed to the production of a cheaper working fluid than ordinary coal-gas. With gas at 1s. per 1,000 cubic feet, the cost of a horse-power would be, as we have said, 0·24d. per hour, or about the same as that of a steam engine burning coal costing 13s. per ton. Now, Professor Ayrton states that this cheap working fluid is supplied by Dowson's gas. About this little or nothing has been heard as yet—in this country, at all events. It appears, however, to be our old acquaintance, water-gas, in a new guise. Steam mixed with air is passed through a column of burning fuel. The steam is decomposed, and we have a mixture of hydrogen and carbon monoxide given off. Professor Ayrton gives its analysis as: hydrogen, 20 per cent; carbon monoxide, 30 per cent; carbon dioxide, 3 per cent.; and nitrogen, 47 per cent. Its calorific value is therefore much less than that of coal gas. Indeed, it appears that coal gas has 3·4 times as much energy as the Dowson gas, which must therefore be 3·4 times cheaper in order that it may be used to the same advantage. As to the cost we know very little. Professor Ayrton exhibited a table, however, during his lecture, in which were set forth all the working expenses of an Otto engine indicating 30 H.P., and working with Dowson gas for 300 days of nine hours each. The figures showed that the engine cost about 45½ per cent. less, power for power, when worked with Dowson gas than when worked with coal gas at 3s. per 1,000 cubic feet. It does not appear, however, that these figures were obtained by actual experiment. A smaller engine driven with Dowson's gas has, it was stated, in practice given results showing that one indicated horse-power was obtained from 1·46 lb of coal, a performance rather better than that of the best modern marine engines. But it is estimated by Professor Ayrton that an engine working to 40 lb. would require but 90 ft. of gas per horse per hour, and would give one horse-power for every 1·2 lb. of coal burned.

Should these statements be verified on further trial, the result will be very important. It is quite true that pipes cannot be laid down and the gas supplied from a central station, but each engine might be provided with its own producing apparatus to take the place of a steam boiler. The question would of course then arise whether the boiler or the gas producer would be the greatest nuisance. The enormous advantage possessed by the coal gas engine would still keep it in use. The only advantage to be derived from a resort to the Dowson gas engine instead of steam would be a small saving in cost of coal. The necessity for skilled labor and the risk from fire would remain about as before. Upon the whole we are disposed to think that the steam engine will find a more dangerous rival in the ordinary gas engine, such as Clerk's, than it will in the Dowson gas engine, which only appears to advantage when compared with engines burning an unnecessary quantity of fuel. We suppose, too, that such a thing as a wasteful or badly kept Dowson gas engine might also exist, when the comparison would assume another aspect.—*The Engineer.*

A NEW MACHINE FOR TESTING THE STRENGTH OF SILK FIBER.

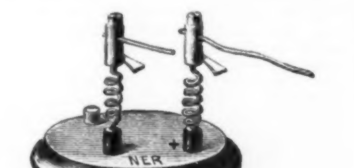
THE young American engineer resident in Lyons, whose silk-reeling machine has been mentioned approvingly by Consul Peixotto, has produced a silk-testing machine which has already been adopted by several American silk manufacturers, has been sent to Japan to test the silk fiber of that country, and has been made a special subject of discussion by the Scientific Society of Lyons. The filature or reeling of silk fiber comprises three careful and necessary operations, the final one of actual reeling making the grege or raw silk, which is the thread that is afterward doubled and twisted. The raw silk is so fine a thread that 280 miles length of moderately fine grege weighs a pound, yet this single thread is made up of four to ten filaments, each derived from a separate cocoon. After soaking in hot water, the filaments from a number of cocoons are pressed together at their ends, which adhere by a natural gum secretion, the thread so started being wound off on a reel until the cocoons are exhausted. This seemingly easy operation is made difficult by the imperative need of uniformity in the thread. Irregularities cause breakages, waste, and knots during spinning and weaving, being thus especially troublesome on American high-speed machinery, and mar the beauty of completed fabrics. Yet so difficult is the reeling and so imperfect the old method of testing irregularities that variations of 40 to 50 cents a pound exist in the prices paid for thread, according to the reputation of different parties for care and success in attaining uniformity, the thread being thicker and thinner than the average in spots, according to the lack of exactness in keeping up a uniform run from the cocoons. The old mode of test consists of cutting off and weighing samples of thread of equal lengths; but this titrage, as it is called, not only lacks delicacy, but is defective, from the obvious fact that errors may balance each other so that their sums shall agree, although full of variations from rule. Here comes in the new tester, the serigraph, which is a machine of extraordinary simplicity, based upon the principle that the resistance of thread under tension varies with its thickness. The machine consists of two small drums or short cylinders, covered with rubber and revolved by the same shaft, and a pendulum, hanging vertically a few feet from the drums but between them, this pendulum bearing an agate hook on its end. The thread to be tested, having first been wound on a loosely turning reel, is passed several times around the first drum, then over the hook on the end of the pendulum, then around the second drum, and thence to a reel, on which it goes from the machine. The pendulum hangs a little out of the vertical line, so that its weight strains somewhat on the thread; the second drum is a little larger than the other, so that its periphery travels 3 per cent. faster than that of the first; hence the second drum tends to demand the thread 3 per cent. faster than the first can deliver to it, the result being to slightly stretch the thread. As the weight of the pendulum is pulling on the strained thread also, the thread will yield more or less according to its thickness, so that the pendulum keeps moving a little accordingly; the pendulum carries a pencil, and a tape travels at a uniform speed in contact with it, the variations in the thickness and strength of the thread thus being recorded by the pencil in a line varying from straight as the thickness of the thread varies. A foot of this diagram—which magnifies the irregularities of the thread 120,000 times—represents a mile of thread, this actual mile of thread being run through in ten minutes; the machine also measures the thread, and is arranged to stop automatically after running off a desired length, besides requiring no attention, the breaking of the thread even being made to stop it.—*N. Y. Times.*

ARTISTIC RAG CARPETING.

POSSIBILITIES in the way of rag designs in carpeting are limited; but certain artistic results may be achieved by close attention to colors, and lengths of color in stripes sewn together for balls for weaving, and by numbering said balls in their order for weaving. The colors and arrangement of colors may be somewhat controlled by exact measurement, and proportion of the lengths of the above strips of cloth when sewing them together. An apparent groundwork of one color broken by an irregular figure of various colors can be obtained as follows: Colored warps are now largely in use; the warp is the hemp foundation in the loom; the "filling" or "woof" is the colored cloths in strips woven in and out across the breadth. For example, say you desire a black ground for your carpet, with broken figures of deep red, full blues, yellow, etc., you must ascertain from your weaver how long a strip must be to allow for the "beating up" in the loom—that is how long a strip will weave one line of "filling" across the breadth; next count down and see how many lines of "filling" go to a yard of carpet. We will suppose it takes a strip fifty four inches in length to weave one line of filling thirty-six inches wide, also that you desire three of the irregular figures across the breadth. You will, of course, use clean woolen cloth; no cotton should be introduced. It must be remembered the following proportions are suggestions merely as to relative length. Take a strip of black cloth twelve inches long; sew it to a strip of dark red cloth six inches long; this in turn to another twelve-inch black strip, to which join a six inch yellow strip. Suppose this forms one line of filling; you must now join another six-inch yellow strip to make yellow come under yellow as the shuttle goes back to the right hand; then join to the yellow twelve inches of black; to this six inches of blue, twelve of black, six of red, and twelve of black; black under black again, and so on until eight or ten filling lines to complete your irregular blocks of color; your balls must then run inches of black sufficient for about two inches of black ground, after which commence figures again, beginning with blue instead of ground; six inches blue, twelve of black, six of yellow, twelve of black, six of red, and twelve of black. Repeat as previously directed, and you will have a black ground with set figures, in colors according to your fancy in scattering them. A fringe of the same material will add to the artistic effect, and may be made by sewing strips of cloth twenty-four inches of black to twelve of red, yellow, blue, or other colors in the figures of the carpet. When a long strip is ready wind it loosely around a five inch wide slat of wood; secure in shape by sewing it with strong thread; slide it off the slat, and sew it to your carpet or rug with double carpet-thread.—*Art Interchange.*

FAURE'S SECONDARY PILE.

FAURE'S secondary piles are finally about to come into use. After numerous studies on forms, dimensions, etc., Mr. Reynier, who has partially taken upon himself their



FAURE'S SECONDARY PILE.—REYNIER'S MODIFICATION.

manufacture, has adopted two types whose arrangement is shown in the annexed figure. These two types are formed of plates rolled around in the form of a helix, as in the first system, and the minium is held against the plates by means of a sort of serge instead of the felt at first used—the latter having been found to rot after comparatively short use. Mr. Reynier has also discarded lead as a material for the vessel, and returned to the glass jars which were employed in the first place; and these he prefers because the operations of the battery can thereby be watched.

In the smaller type the diameter is 10·5 centimeters and the height 18 centimeters; the element contains half a liter (nine-tenths of a pint) of acidulated water; the surface of the plates is 12 square decimeters—six for each plate; and the total weight of the element is 4 kilogrammes.

The larger model weighs 8 kilogrammes, and contains a liter of acidulated water. Its diameter is 13 centimeters, its height 25 centimeters, and it contains two plates whose total surface is 36 square decimeters. This size is adapted for industrial purposes, while the smaller will be preferred for laboratory experiments and domestic uses, such as for running sewing machines, etc.

Mr. Reynier has made no endeavor to construct light batteries, but he thinks that the weight of the elements may be reduced by at least one half.

A NEW ELECTRICAL STORAGE BATTERY.*

THE great utility of some thoroughly practical method of conserving electric force has caused a great deal of attention to be applied to the subject; no system of electric supply can be considered as perfect until some means is used to so store the force generated that it may be drawn off equally and regularly, and this whether the generator be on or off. If we take, as an example of electric supply, the present systems of electric lighting, it is at once seen, should an accident or stoppage take place in the machinery generating the current, the whole of the apparatus such as lamps or motor-machines are influenced; should there be a reservoir of electricity between the generator and the apparatus of whatever sort for utilizing the force this inconvenience would not occur.

All the present systems of storing electricity depend on certain chemical changes produced by electrolysis.

I have gone through a long series of experiments on storing electricity and made many forms of cells, one being a porous pot containing dilute hydric sulphate and a sheet of lead, in an outer vessel containing a sheet of lead in solution of acetate of lead, the plate in the porous pot being made the positive electrode; this cell had the power of storing electricity, by peroxidizing the positive electrode, and depositing from the acetate of lead solution metallic lead on the negative electrode, the hydrogen having combined to form acetic acid. On discharging the peroxide is reduced, and the oxide formed during discharge on the other plate dissolves in the acetic acid, forming the original solution of acetate of lead. By this means I eliminated the injurious effects of the hydrogen on charging.

During my experiments I found that red oxide of lead is a very bad conductor of electricity, and the peroxide a good conductor. I also discovered that by amalgamating lead plates with mercury a marked increase was immediately manifest in polarization effects, the plates becoming more uniformly and rapidly peroxidized when used as positive electrodes, and local action entirely disappearing. These mercury amalgamated plates at once give me an advance of other cells. I used them in many ways, constructing cells in which the positive plate was amalgamated, and the negative coated with red oxide, or with peroxide, produced by treating red oxide with dilute hydric nitrate till the brown precipitate of peroxide fell, the precipitate being washed and painted on the electrode. I also amalgamated the negative electrode simply. I found that in every way positive electrodes amalgamated produced the best results. I also made cells in which either peroxide or red oxide was formed into a porous conglomerate, using the conglomerates as electrodes, immersed in dilute hydric sulphate. I constructed cells with parallel plates; red oxide or peroxide being filled in between the plates; in this experiment red oxide is useless and peroxide efficient. In all these experiments I succeeded in storing electricity to different extents.

Having thoroughly satisfied myself that positive electrodes amalgamated with mercury were the best, I investigated the behavior of various forms of negative electrode, having in view the conservation of the hydrogen; this I thought to do by occluding the hydrogen in suitable electrodes, as spongy platinum or metallic palladium; but as both these methods would be useless owing to expense I did not even experiment on them.

I further thought of having negative electrodes, whose oxides should be soluble in the solution, and which could be redeposited from the solution, or of having metallic solutions from which metal could be deposited, the resulting solution being such that should, on the oxidation of the deposited metal, combine with the oxide and again form the original solution.

I thought that success in this manner would result in a powerful and constant source of store energy, the cell would not polarize itself during discharge, as is the case in both Planté and Faure cells; in these cells the peroxide formed by the discharge produces a contrary electromotive force.

Experimenting from this train of thought, the results I have obtained are such as to have an important practical bearing on the future of electric work.

The experiments comprised amalgamated lead as a positive electrode with negative electrodes composed of either zinc, iron, or copper, in each case the solution between the electrodes being a salt of the metal composing the negative electrode. With zinc, sulphate of zinc was the solution; with iron, sulphate of iron; and with copper, sulphate of copper. In all these cases the results were not only far more powerful than with any other form of cell I had previously devised, but also very constant, the polarization lasting many times longer than in any other form of cell. The cell with zinc negative electrode I discarded, owing to the necessity there would be to keep the zinc plate amalgamated to prevent local action; the iron negative electrode was set aside owing to the iron oxidizing when the cell was not in use. The cell having a negative electrode of copper, a positive electrode of lead amalgamated with mercury and a solution of cupric sulphate, I have adopted as a thoroughly economical, lasting, and practical form of storage reservoir. The chemical changes in this cell are exceedingly interesting and beautiful, the cell being composed of a sheet of lead cleaned with dilute sulphuric acid and amalgamated thoroughly with mercury, and a sheet of thin copper a little shorter; the two sheets are perforated with a number of holes and then rolled in a spiral, separated by rubber bands cut every five inches, the holes in plates and cuts in rubber bands being to allow free circulation of the solution (the short plate being uppermost before rolling). This combination is immersed in a solution of cupric sulphate, and the amalgamated lead plate made the positive electrode of a suitable source of electricity, the chemical action being that the oxygen of the decomposed solution combines with the lead, forming a perfectly even coating of the insoluble peroxide, the hydrogen replacing the copper of the solution, and the copper being deposited in the metallic state on the negative electrode. As the decomposition of the cupric sulphate proceeds, the solution gradually loses its azure blue color, becoming more acid, and finally when the whole of the copper is deposited, we have the solution colorless and transformed into hydric sulphate and water, the positive electrode peroxidized and copper deposited on the negative electrode. During discharge the peroxide is reduced and the copper element oxidized, the oxide combining with the acid and forming cupric sulphate, the solution returning to its original color. This change of color forms a beautiful means of telling when the cell is charged; it is a veritable charging gauge. The power of this cell is very great and very constant; it can be made to last for hours, the time being dependent on the quantity of cupric sulphate decomposed.

I have, by the decomposition and recomposition of one pint

* "On a New Electrical Storage Battery." By Henry Sutton, Ballarat, Victoria. Communicated to the Royal Society by the President.

of cupric sulphate, obtained over two hours' effective work in heating to a red heat one inch of No. 28 iron wire, the cell measuring internally four inches deep and four inches diameter.

I constructed cells with free crystals of cupric sulphate suspended in the solution, and found that the presence of free crystals prevented the oxidation of the amalgamated lead electrode, it being essential that the solution become slightly acid before the peroxide will form. The cell during charging gives out a peculiar rattling noise, which I consider due to the deposition of copper on the negative electrode altering the form of the spiral.

A practical form of cell for storing purposes ought to be made by fixing a series of amalgamated lead plates in a box in grooves, as in Cruikshank's trough battery, filling the interval between the plates with solution of cupric sulphate, and passing a current through of sufficient tension to overcome the contrary electromotive force of the series, the positive sides of the plates being peroxidized and copper deposited on the negative sides. I have two boxes on this plan, each containing twenty-five plates, the total being equivalent to fifty cells. By this means batteries of great tension can be charged from thirty Bunsens. A number of twenty-five plate boxes can be coupled for quantity of charging, and for tension during discharge. Twenty such boxes, one foot square, internal measurement, will give in series a battery of 500 pairs of one foot square plates.

It will be seen from the foregoing that this method of conserving energy has a wide field before it, and as it will benefit fellow-workers in science, placing in their hands a means of experimenting with powerful electric currents, I give it without reservation, freely and untrammeled by patent rights, for their use.

THE DISSOCIATION OF CHEMICAL COMPOUNDS.

THIS was the subject chosen by Dr. William Wallace for his recent opening address to the Chemical Section of the Philosophical Society of Glasgow. He spoke as follows, illustrating his remarks by numerous experiments:

There are in chemistry two great and leading methods of research which have contributed equally to the advancement of our knowledge of the relations of the various elements to one another. One of them is called analysis, or decomposition, or dissociation (although the last-named term expresses analysis in a somewhat restricted sense); the other is denominated synthesis, or combination. It is to the first of these methods of inquiry that I shall ask you to follow me in the remarks I shall address to you, and chiefly in the more limited sense implied in the term "dissociation."

The word "analysis" in chemistry signifies a separation or splitting-up of a body into its component parts, such separated parts differing from each other and from the original body from which they were taken. This definition of analysis at once distinguishes chemistry from physics in the restricted application of the word. If we take a piece of marble, we can examine it either physically or chemically. In the first case we may estimate the exact size of the stone; its absolute weight in pounds, grammes, or grains, as the case may be; its weight, as compared with that of an equal bulk of water, or specific gravity, as it is usually termed; its relation to light, heat, and electricity; its comparative hardness, and many other qualities. We may also, by mechanical means, break the lump in pieces and reduce it to powder; but each minute fragment will still be a piece of marble, unchanged in all its properties. How different is a chemical examination! The application of acid at once discloses the fact that the mineral contains a gas, and also a body which dissolves in the acid, forming a clear solution, from which it may afterwards be obtained by appropriate means. This is analysis, or decomposition. The same mineral—which is simply one of the many forms of limestone—if exposed to a full red heat, in a furnace, is separated into its constituents; lime remains behind, while carbonic anhydride—or, as it is commonly called, carbonic acid gas—escapes with the products of the combustion of the coal, although it can readily, by appropriate means, be collected and its properties examined. This is dissociation, or the separation of a compound body into its constituents, without the intervention of any other chemical agent. By various methods—some extremely simple, others highly complex—all substances, animal, vegetable, and mineral, within our reach, have been analyzed, or decomposed, or dissociated, until we have arrived at a number of bodies which we call elements—about sixty-five in number—and which we have never yet been able to tear asunder into any simpler form of matter. Of these the greater number are metals, while a comparatively small proportion—about one-fifth of the whole—are either gaseous or possess properties of an opposite character to those of the metals. Among the latter I may mention sulphur, phosphorus, iodine, bromine, and carbon. The distinction between the metals and non-metallic elements is not, however, so precise and absolute as might at first be supposed. Phosphorus is closely allied to the metal arsenic; the metal chromium forms compounds like those of sulphur; and there are many other singular analogies. It was long accepted as an axiom in chemistry that the gas hydrogen was a metal, or acted the part of one; but it has, within the last few years, actually been condensed by intense pressure and extreme cold into a liquid, and even into a solid metal. Of this, however, I shall speak further on.

The forces by which bodies may be dissociated are various, but by far the most important is heat. In many cases compounds appear to have their constituents grouped together so loosely that the most insignificant application of forces suffices to break them up. Thus the compounds usually called chloride and iodide of nitrogen (consisting of ammonia, the hydrogen of which is more or less completely replaced by chlorine or iodine) explode with violence on being touched with a feather, or by mere agitation of the air by which they are surrounded. The green hydrated oxide of copper holds its combined water so feebly that, on heating to the boiling point, even below water, it is separated, and the black anhydrous oxide is produced. A weak solution of the crystallized chloride of cobalt, on being heated to boiling in a sealed tube, one-third full, changes from the hydrated to the anhydrous condition, the separation of the water of hydration being made apparent to the eye by the liquid changing from pink to blue. Many ammoniacal salts become dissociated to a certain extent on their solutions being heated. The oxides of mercury are readily decomposed at a low red heat (600° to 700° Fahr.) and those of silver, gold, and platinum all give off their oxygen, leaving the metals in a pure condition, on exposure to a moderate heat. In other cases the decomposition is only partial, as when the black or binoxide of manganese is converted into the lower brown oxide; when chromic acid gives off half its oxygen, and becomes the green oxide of chromium; when iron pyrites gives off part of its sulphur; and many other cases of a similar nature.

Heat is only one of the many forms of force by which compound bodies are affected. Light has a distinct power of decomposing many chemical compounds. The salts of silver are particularly sensitive to light, and the art of photography depends entirely upon the effect of light on silver salts and other compound bodies. Vegetable colors are also readily changed by light; but by far the most important function played by light in decomposing compound bodies is displayed in the phenomena of plant life, in which carbonic anhydride, water, and ammonia are decomposed, and their elements re-arranged so as to give rise to an infinite multitude of new combinations, while oxygen gas is freely given off.

Electricity is a potent agent of dissociation, and is frequently used by the chemist, especially for the separation of metals from their solutions. One of the most familiar illustrations of the action of voltaic electricity upon chemical compounds is the decomposition of water, in which the two gases of which it is composed—oxygen and hydrogen—pass off from the two electrodes or terminals of the wires of the battery. A convenient form of the arrangement, as a lecture illustration, is that in which the gases, as they stream off, are collected in graduated tubes, so that the analysis is really quantitative.

Although it is wandering a little away from our subject, it may be interesting to consider for a moment how it is that the gases appear at the two poles, which may be many inches apart. If we take a molecule of water, composed of one atom of oxygen and two atoms of hydrogen, and suppose this molecule to occupy a position in close contact with one of the poles, we can understand how one of the gases, say the oxygen, is evolved at that pole; but how does the hydrogen travel to the other pole? The answer to this is, that it does not travel at all, but unites with the oxygen of the nearest molecule of water in the direction of the current, which in turn gives up its hydrogen to the next molecule, and so on until the other pole is reached and the gas is disengaged. We have, as it were, a polarization of the water, by virtue of which we may conceive that a series of molecules are distorted so as to have their oxygen pointing in one direction and their hydrogen in the other, the ultimate effect being as I have stated.

I may make another digression, but only for a moment, to ask your attention to the terms atom and molecule. With regard to atoms, we know what is the *relative* weight of these, and, in the case of gases, their *relative* dimensions; but of their actual weight or size we are, and must ever remain, in ignorance. It is true that in the case of certain elementary gases, mathematicians have made estimates of their probable size (for example, it has been calculated that an atom of hydrogen does not exceed one-five-millionth of an inch in diameter); but even in such estimates as these we cannot tell whether we are dealing with ultimate atoms or molecules composed of an aggregation of atoms. It is certain that some gases, such as chlorine and iodine vapor, are composed of molecules or grouped atoms, since these can be dissociated by heat, the gases expanding in volume when the dissociation takes place. Neither can we tell whether elements, in combining together, unite atom to atom or molecule to molecule. In water, one of the simplest of chemical compounds, since it contains only two elements, we have oxygen and hydrogen in the proportion of one atom of the former to two atoms of the latter. But we cannot tell how these atoms are grouped. We can represent it with an atom of oxygen in the center; with one of hydrogen on each side; or with one oxygen above and a double atom of hydrogen below. But these are not at all likely to be correct. It is almost absolutely certain that the molecule of water has a geometric or solid figure, which could not be made up of less than six atoms, and probably is much more complex. A system of representations of compound bodies by diagrams, called graphic formulæ, have for some years been employed by some of our leading chemists, and are said to be useful in teaching the science. To my mind they form a stumbling-block rather than an assistance to the student, who is constantly confronted with representations of arrangements which cannot by any possibility exist in nature.

Other examples of the dissociation of compounds by electrical agency might be mentioned; and in the practical arts the deposition of metals has now become an industry of enormous dimensions.

To return to the action of heat in its action upon chemical compounds, I have now to carry you a little further. We have seen that many compounds are readily decomposed; but there are others which require the highest temperature at our command for their decomposition. Until very recently water was supposed to be incapable of being separated into its elements by heat alone. By an ingenious contrivance Sir William Grove succeeded in effecting the resolution of this compound, and in this way: In a flask water was made to boil, and in a tube which received the steam a succession of electric sparks were passed from a Ruhmkorff coil, and the steam further on was condensed, while the gases formed by the dissociation of the watery vapor by the intense heat of the electric spark were carried forward by an aspirator, or Sprengel pump, into an appropriate receiver. In this case the gases, once separated, were pushed on by the large volume of steam, otherwise they would have re-combined. In many experiments in the laboratory we use the electric spark to explode mixtures of oxygen and hydrogen, and it is, in fact, the only means we can employ if we have to measure the amount of condensation which follows the explosion. We can readily produce, in furnaces, degrees of temperature amply sufficient for the decomposition of water (2,000° C., or 3,632° Fahr.), and there is not the slightest doubt that such decomposition is constantly taking place; but the gases are immediately re-combined. There are, too, complications in this case—the carbon of the fuel reacts upon a portion of the watery vapor, and carbonic oxide and carbureted hydrogen result, which, on the top of the fuel, burn to carbonic acid and water—exactly the same result following as if there had been no decomposition of the water. As the heat absorbed or rendered latent in the act of decomposition is exactly equivalent to that which results from the subsequent combustion, it follows that the introduction of steam into a furnace does not increase the gross amount of heat due to the combustion of the fuel, but it frequently has the useful effect of carrying forward in the furnace the zone of highest temperature, and so serves a useful purpose.

Perhaps the most important example of dissociation presented to us within a comparatively recent period is that of carbonic acid gas, which was effected by Deville in 1868. This eminent chemist showed that at an extremely high temperature carbonic acid is dissociated into carbonic oxide and oxygen. Further than this, carbonic oxide is decomposed, two atoms of it giving one atom of carbon and one atom of carbonic anhydride, the ultimate result being the resolution of the original compound into carbon and oxygen. A peculiar arrangement is required for the performance of this process; a ring of metal kept cold by a current of water being close to the gases, heated to an intense degree by the electric spark, and the carbon is deposited upon the cold metal. I consider this a most important discovery, not merely as a scientific fact but as an explanation of phenomena which could not otherwise be accounted for. In an ordinary furnace, such as those employed in the Siemens-Martin process, and others in which an intense heat is obtained, there is evidently a limit beyond which no further increase of temperature can be obtained; for this reason, that carbon and oxygen refuse to combine at a very exalted temperature, the exact degree of which we cannot accurately define, but which has been estimated at about 5,400° Fahr.

In the compounds of carbon and hydrogen we have a more familiar illustration of dissociation. If we pass one of the gaseous hydrocarbons, containing a large proportion of carbon—such, for example, as ethene (C_2H_4), popularly known as olefiant gas, or the vapor of a liquid hydrocarbon such as benzene, or of a solid such as naphthaline, through a glass tube heated to bright redness, a deposit of carbon takes place, and the gas or vapor that passes on contains a greater or less proportion of methane or marsh gas (CH_4). This is a well-known fact in some manufacturing processes. In gas making, the retorts, especially at the back, become coated, often to the extent of several inches in thickness, with a solid deposit of carbon, which results from the decomposition of the gaseous liquid and solid hydrocarbons evolved from the coal by the action of heat. We may go further than this, and say that the production of illuminating gas from coal is itself an illustration of dissociation, for carbon is left behind, mixed with the mineral matter of the coal, forming coke, while the hydrogen and oxygen combine with a portion of the carbon, forming gaseous and liquid hydrocarbons and carbonic oxide, besides some other compounds containing sulphur and nitrogen. Again, if we distill coal tar or crude paraffin oil we obtain in the retort or still a portion of solid carbon and a distillate of oils containing less carbon than the original liquid. If we bring paraffin oil drop by drop, or in a thin stream, into a gas-retort heated to bright redness, a thin and poor gas is obtained, and much solid carbon is set free, but at a low red heat a rich gas is produced, with no carbonaceous deposit. But to pursue the subject further, marsh gas, by exposure to a still higher temperature, either by the electric spark or in a porcelain tube placed in a furnace, yields hydrogen and a richer hydrocarbon, acetylene (C_2H_2), which in turn is decomposed into carbon, hydrogen, and some marsh gas, the ultimate result being that all hydrocarbons are resolvable by heat alone into carbon and hydrogen.

I could dwell on this subject much further, but it is unnecessary. Let us now see to what conclusion these experimental results lead. It is simply this—that by the action of heat all compound bodies are resolvable into their elementary constituents, and that if we had a world, or planet, or sun, the temperature of which was sufficiently high, we should there have simply a collection of elementary bodies. This is a conclusion to which we are forced by experiment and analogy. Some of us may not be able to realize the existence of such conditions as I have stated as being necessary, but we must acknowledge that, if such conditions did exist, the result would follow, just as we accede to the statement that if water is exposed to a sufficiently low temperature it will freeze.

THE PHYSIOLOGICAL ACTION OF COFFEE AND SUGAR.

ACCORDING to the *Revue Industrielle*, Dr. Leven recently communicated to the Biological Society of Paris a paper in which he gave the results of experiments made by him on dogs for the purpose of studying the action of coffee.

The action that this beverage may possibly exert on the animal organ has been often discussed. The majority of medical men are disposed to agree that coffee stimulates the circulation and brings about a hypersecretion of gastric mucus, but no proof has been offered in support of such assertion.

A contrary opinion is held by a certain number of physicians, and, among them, Dr. Leven. On the present occasion the latter gentleman recalls the observations that he made a few years ago on coffee absorbed by frogs, rabbits, and guinea-pigs. The extract was found to retard the movements of the heart, to increase the tension of the arteries, and to dilate the pupil. In certain cases, caffeine has been used as a substitute for digitaline, the characters of which it exhibits to a less degree.

The most recent researches of Dr. Leven are as follows:

He gave a dog 200 grammes of meat, and then administered to him an infusion of 36 grammes of coffee in 150 grammes of water. The animal having been killed, it was found that the stomach still contained 145 grammes of meat, while under identical conditions the stomach of another dog to which no coffee had been given contained no more than 100 grammes. The abdominal mucous membrane was found to be pale, and the blood vessels greatly contracted. The result would seem from this to be that coffee, by causing anæmia of the stomach, impedes digestion, and that the use of the beverage will finally bring on dyspepsia. As well known, English physicians have greatly insisted on the point that an excess of coffee and tea often brings about gastralgia, dyspepsia, and, at the same time, troubles more or less profound of the nervous system. It becomes necessary, then, to distinguish between the local anæmia produced on the stomach by coffee and the more general action that it exerts on the central nervous system—an action that has caused it to be considered an intellectual beverage.

Sugar, according to Dr. Leven, acts entirely otherwise, and is a substance eminently qualified to promote digestion; and he is therefore accustomed to prescribe it in certain cases of dyspepsia. He cites on this subject the following experiment: There were given to a dog 80 grammes of sugar along with 200 grammes of meat. The dog having been killed six hours afterwards, there were found in his stomach only 20 grammes of undigested meat. The mucous membrane was found to be red and swollen, and the liver was entirely congested.

The conclusion to be derived from these researches is that coffee, when used, should be made weak and should be very much sweetened in order to facilitate the work of digestion. There are so many persons interested in this subject that we have thought it of interest to make Dr. Leven's researches known.

SEASICKNESS.

JAMES REGINALD STOCKER, M.B., M.R.C.P., medical officer in the service of the Cunard line of steamships, contributes to the February number of the New York *Medical Journal and Obstetrical Review* an article in which, after deprecating the tendency to resort to special drugs in a routine manner in the treatment of seasickness, he suggests the following theory of the mode in which the affection is produced: The pneumogastric nerve sympathizes with the senses and the intellect, and plays an active part in that expression of disgust which results in vomiting. Stimulation of the nerve, in moderation, favors digestion and the various other processes of organic life; in excess it irritates them. It directly occasions nausea, dyspepsia, flatulence, vomiting, etc.; and, indirectly, all the other sad effects of seasickness. The nervous centers, excited by the sensory impressions, become at last so irritable that the introduction of anything into the stomach is resented, and vomiting occurs; until sooner or later the nervous system is dominated by that potent influence for good or evil, the force of habit, and the body finally becomes accustomed to the new sensation. He thinks that the fifth sense, commonly called the "sense of touch," or "common sensation," is a compound sense. By its means we are able to recognize not only touch and its varieties, but also distance, form, size, weight, consistence, relation, and time, and sometimes even color and sound. The study of seasickness teaches us that there is in us a sense which, without some such experience, we might perhaps be slow to recognize—the sense of passive motion. It may not indeed be so exalted a sense as others, nor so important, but it is certainly one which in seasickness deserves consideration. And after all it has its pleasant as well as its painful side, when used in moderation; it is the placid sensation that often lulls the child to sleep; it is that of the rocking-horse, the rocking-chair, horse exercise, vehicular motion of all kinds, passive movement of the body in all its forms and phases, only unpleasant, only disagreeable when used inopportunely or in excess. Conditions which some other observers refer to the falling weight of the viscera, the author is inclined to attribute to a cause a little more remote, but produced partly by that agency. He believes that the feeling of nausea, etc., which ensues upon the falling of the vessel is the same as that due to the backward movement of the swing, or of any vehicle, the downward movement of an elevator, vertical or oblique, as well as in the dance, etc.; and is brought about by the formation of a partial vacuum in the lung. To this cause he also attributes the condition known as *mal des montagnes*. We have in seasickness conditions almost precisely similar to those of the latter affection, with regard to the effect as well as to the cause: a certain rarefaction of the air within the chest; a partial vacuum produced, not indeed by the rarefaction of the atmosphere itself, but by the subsidence of the abdominal viscera when the vessel falls, and therefore felt more in the upright than in the horizontal position; and the continued movement of the body. The first, *i. e.*, the want of air, is the cause more particularly of that feeling of "goneness" we so often hear complained of. The author has been in the habit of recommending patients to take a deep breath whenever they felt that sinking at the pit of the stomach, having found it by experience to be an effectual, though not infallible, means of allaying the sensation, and to this he would refer the good effect of singing or of any rhythmic movements that may tend to relieve the mind or to regulate the breathing, as well as the advantage sometimes derived from weight or pressure applied to the stomach by elastic and other belts or bandages. The second, *i. e.*, the movement, is the cause more especially of the irritable condition of the nervous system. The secret of the one is its direct effect upon the pulmonic branches of the pneumogastric nerve, probably the result of a partial paralysis. We know that division of the pneumogastric causes vomiting; the nerve is said to exert an inhibitory effect upon the heart; it has the same effect upon the stomach. It may, however, be due to stimulation of the pneumogastric, for the diminished resistance of the air, according to Liebig, leads to more active elastic contraction of the lung. The secret of the other is its indirect effect upon the same nerve, through the media of the nerves of feeling or common sensation, sometimes indeed through the agency of other senses, as *e. g.*, by the sight of undulating movements, and by other unpleasant sensations. In each case, practically, the cause is of an eccentric or peripheral character. Similar views, the author remarks, were expressed, some fifty years ago, by Herbert Mayo. As to the treatment, sedatives, both nervine and also stomachic (for they too will influence the terminal branches of the pneumogastric nerve), anodynes and anæsthetics, including amyl nitrite, are good. So also are stimulants. Aperients are exceedingly useful. But in this, as well as in most other complaints, there are certain stages or periods: the first, one of great nervous depression; the second, one of gastric and nervous irritability; the third, one of exhaustion. Things which are useful or harmless in one way may be useless and even hurtful in another. There are drugs which serve to diminish and even to deaden sensibility—some which serve to fortify and to strengthen it. Some drugs are no doubt of use, of much use, for the relief and prevention of seasickness; but that they are specifics the author most directly denies. A person's consciousness or his intellect may be so completely fuddled that he may not know what he is about; but to call that a cure is not calling things by their right names. The use of the bromides for this purpose is increasing daily, and he cannot but condemn the practice of using them so indiscriminately and in such large quantities as has lately been recommended. But, while there is no specific remedy or panacea for the disorder, many of the conditions may be relieved by medicine. Seasickness, after all, is but a form of passive indigestion, the result of a functional neurosis in which the pneumogastric nerve is either excited or depressed. Like many other functional disorders, if anything is to be done at all for it in the way of medicine, it requires to be *treated*. One is sometimes surprised at the complete failure in some cases of a remedy which in others has proved of great service; and, conversely, one is sometimes charmed with the effect of a remedy on some which has failed completely with others. With regard, for instance, to the use of alkalies as stomachic sedatives, one seems sometimes to hit upon by chance, to distinguish intuitively, or rather, perhaps, to learn by experience, what particular drug to use in each individual case. The same may be said with regard to aperients, etc. Thus are to be explained the differences and agreements in the opinions of writers. One cure, indeed, there is, viz., custom or habit. In the course of time it almost invariably asserts itself, and "use becomes a second nature." The sooner one can accustom or habituate one's self to the altered condition of things, the sooner will one become a good sailor. The best means of doing so is to forget it, to banish it from one's memory by the substitution of gymnastic and other exercises, and by learning the art of balancing one's self. The more one is able to forget one's self, the more one's attention can be distracted from one's own condition and diverted to other things and other people, the less will one feel the disagreeable sensations. What people want on board ship is resolution, and, when the will is not sufficient and moral means have failed, the most effectual, though not by any means the most practicable, is to have recourse to force.

OLEOMARGARINE.

IT is now doubtless known to most people that much of what by courtesy goes by the name of butter is only very distantly related to the dairy produce which has hitherto enjoyed a prescriptive right to that appellation. If any of our readers were ignorant of this fact, the interesting and instructive statement which the chairman of committee, in his capacity as a private member, laid before the House during the last session will have fully enlightened them on that point, as indeed it enlightened, and seemingly astonished, honorable members. During the past ten years a new industry has been created. It came into existence very quietly, and under the taint of illegitimacy, and consequently the world in general knew very little about it. Thanks, however, to the operations of sanitary boards, officers of health, and food analysts, it was eventually dragged out into the light of day, when, despite the circumstance that the greater part of its existence had been spent in out-of-the-way places and without the fostering recognition of authority, it stood revealed as an astonishingly well-grown and highly prosperous business.

The industry in the outset was set going to manufacture a product from beef-suet to be used in the adulteration of butter, and enormous quantities of this product were made in this country and in America for this purpose. The fraud was, however, so repeatedly exposed, and convictions against grocers and others selling this adulterated butter were so frequently obtained, that the venders were driven to so far take the public into their confidence as to declare that the product was "a butter substitute," and hence arose the euphemism of "butterine," by which it became generally known. Now these remarks are in no sense derogatory to the value of this product as an article of food.

We quite agree with Dr. Playfair that "butterine" may be, and frequently is, very much better than many qualities of butter; but this fact cannot be held to defend or extenuate the practice of substituting "butterine" for butter without the knowledge and consent of the purchaser. The common-sense of buyers and sellers has practically settled this point. The manufacture of "butterine" has now reached such extraordinary proportions that we are bound to recognize it as a legitimate industry: the substance is now sold openly for what it is and on its merits, and it is perfectly obvious that it supplies a public demand.

A recent report by Mr. Bateman to the Board of Trade, on the manufacture of these "butter substitutes" in the United States, throws fresh light on the subject, and the statistics which the report contains are calculated to afford a very precise idea as to the magnitude of the industry. The greater part of the substance is made in the States by the patented method of M. Mége Mouries. The process is as follows: The beef suet, on arriving at the factory, is thrown into tanks containing tepid water, and after standing a short time it is repeatedly washed in cold water, and disintegrated and separated from fiber by passing through a "meat-hasher" worked by steam, after which it is forced through a fine sieve. It is then melted by surrounding the tanks with water of a temperature of about 120° F.; great care is taken not to exceed this point, otherwise the fat would begin to decompose and acquire a flavor of tallow. After being well stirred, the adipose membrane subsides to the bottom of the tank, and is separated under the name of "scrap," while a clear yellow oil is left above, together with a film of white oily substance. This is removed by skimming, and the yellow oil is drawn off and allowed to solidify. The refined fat, as the substance is now termed, is then taken to the press-room, which is kept at a temperature of about 90° F., and is packed in cotton cloths and placed in galvanized iron plates in a press; on being subjected to pressure oil flows away, and cakes of pure white stearine remain: these find their way to the candle-makers. The oil is known as "oleomargarine;" it is packed in barrels for sale or export, or is directly made into "butterine" by adding ten per cent. of milk to it, and churning the mixture. The product is colored with annato and rolled with ice to "set" it; salt is then added, and the "butterine" is ready for packing in kegs. The taste of "butterine" is described as being similar to that of second-class butter, but it is rather more salt; owing to the very small quantity of the characteristic fats of natural butter—the so-called "butyrin," "caprin," etc., which it contains, it lacks the flavor of high-class butter. On the other hand, as these fats are specially liable to become rancid, butterine is free from the disgusting smell and taste of the lowest class butters.

The composition of natural butter and of "butterine" may be stated as follows:

		Butter.	"Butterine."
Water		11·968	11·203
Solids		88·032	88·797
		100·000	100·000
Insoluble Fats	Olein, Palmitin	23·824	24·893
	Stearin, Arachin, Myristin	51·422	56·298
Soluble Fats	Butyrin, Caprin, Caproin, Caprylin	7·433	1·823
Casein		0·192	0·621
Salt		5·162	5·162
Coloring matter		trace	trace
		88·032	88·797

It will be seen that in the main "butterine" is very similar in chemical composition to butter, and its value as an article of food is probably quite as high. Indeed to some people "butterine" might possibly be more wholesome, owing to its comparative freedom from the readily decomposable fats which are apt in some cases to be specially disagreeable; for cooking purposes it may be safely averred that the artificial butter would be generally preferable, owing to the ready alteration of butyrin and its congeners by heat.

The yield of oleomargarine is found to be about thirty-five per cent. of the beef caul fat employed, and its present retail price may be set down as about one shilling per pound. It is very difficult to obtain an accurate return of the production of oleomargarine and butterine; but it is certain that in the Eastern States of America alone the yearly manufacture is not less than ten million pounds. Chicago and the West, moreover, contribute their share, and Mr. Nimmo, the chief of the United States Statistical Department, states that the export of oleomargarine for the year ending June 30, 1880, was close upon nineteen million pounds. Probably this is underestimated, for it is almost certain that considerable quantities of "butterine" passed through the customs under the designation of butter.

The exports of oleomargarine from the port of New York in 1879 and in the first nine months of 1880 are given in the annexed table:

Cleared for	Year 1879. Pounds.	January 1. to Sept. 30, 1880—nine months. Pounds.
Rotterdam	11,931,174	11,127,574
Antwerp	173.537	1,367,526
London	188,426	58,639
Liverpool	1,091,266	590,974
Glasgow	274,023	1,399,694
Other ports	222,438	1,215,246
	13,880,864	15,759.653

Of the fifteen and three-quarter million pounds which were exported in the first nine months of 1880, twelve and a half millions went to Holland, there to be churned into butterine, most of which is sent into this country. Statistics show that the import of "butterine" into this country from Holland goes on in the same ratio as the import of oleomargarine from the States into Holland. The poor British farmer has indeed cause to grumble: for not only do the Americans, as he says, send him "acres and acres" of bad weather, and upset all his calculations as to his crops, but the 'cute Yankee and the persevering Dutchman between them give him no chance even with his dairy produce! The world in general, however, will not complain of "butterine," provided that its composition does not differ materially from that shown by Dr. Mott's analysis given above; but unfortunately from its very nature and the somewhat anomalous position it even yet holds, it is very liable to sophistication, and the people who adulterate butter with oleomargarine are liable to get the oleomargarine adulterated to begin with. An ingenious American has recently sought to place butter, as he calls it, *on a soapstone basis*, by which is implied that finely-ground soapstone added to the fat will, in his opinion, make a marketable commodity! We are told, on high authority, that if we ask for bread we are not to be offered "a stone;" neither are we when we ask for butter.—*T., in Nature.*

[COUNTRY GENTLEMAN.]

ON THE HARM DONE BY EARTH-WORMS.

IN view of the recent works of Darwin and Hensen upon the habits of earth-worms, in which the really stupendous power of these creatures to consume organic matter, and to throw up fine earth upon the surface of the land, has been explained and insisted upon, it becomes doubly important for practical men to keep clearly in mind the harmful character of these worms and to give more attention than has ever been given before to the questions how best to avoid or destroy them.

THEIR NUMBERS—WHAT THEY EAT.

As every florist knows, the presence of worms in the earth of a flower-pot is an evil that needs to be carefully guarded against. Indeed, the fact is only too familiar to multitudes of non-professional persons who grow, or try to grow, plants in the windows of dwelling houses, that in case "earth-worms get into the pots," they do in some way exert a highly pernicious influence upon the prosperity of the plants. The inference is plain that if a single worm in a flower-pot can do actual visible harm to the extent which florists and "window gardeners" are accustomed to witness, there is good reason for farmers and gardeners to consider well, in field practice, what kinds and degrees of injuries are likely to be caused by the great multitudes of worms with which some soils are infested. Hensen computed from one of his observations in a garden that the soil of that particular place contained more than 53,000 worms to the acre, and that the weight of this number of worms would amount to some 350 pounds, and Mr. Darwin remarks that this estimate seems to him credible, judging from the number of worms which he has sometimes seen, and from the number daily destroyed by birds without the species being exterminated. It should be remembered that the subterranean residence and nocturnal habits of earth-worms tend to keep them out of the sight and out of the mind of the farmer, and that it is commonly easy enough, in field practice, to ascribe to a variety of other probable causes injuries which are actually due to these worms. It is when the worm and his works are confined to a limited space, as in the case of the flower-pot, that we have full opportunity to estimate what damages may be occasioned by him; and from the analogy of this tangible, manageable experience, so familiar in floriculture, it is hard to escape the conviction that the earth worm is, in general, pernicious, both in horticulture and in agriculture.

With some noteworthy exceptions, it would appear that comparatively little thought has been given, thus far, by farmers to the question what harm may be done to the land, or to crops, by earth-worms. Besides the complaints of the florists, the chief objection to earth-worms has come hitherto from those gardeners who are charged with the care of lawns. Much annoyance is, in fact, caused by worm-casts upon close-mown lawns in damp situations; but here the difficulty is unlike those encountered by the florists. The damage caused by worm-casts upon lawns seems, indeed, at first sight, to be so purely superficial and mechanical that the consideration of this instance alone would hardly have been sufficient to lead any one to the conclusion that earth-worms are generally hurtful to field crops. It has been supposed, indeed, by many writers, since the time of White of Selborne, that worms do good by "boring, perforating, and loosening the soil, and rendering it pervious to rains and the fibers of plants;" by permitting air and roots to penetrate deeply into the earth; by promoting drainage; by sifting the finer particles of earth from those which are coarse, and by supplying fine, rich earth for the nourishment of plants. The German observer Hensen even went so far as to urge that worms might perhaps be put to practical use in the reclamation and cultivation of sterile tracts of land; his idea being that worms should be transplanted to the barren soil, together with a supply of nourishment pro-

per for their support, but in these somewhat partial commendations there lurks a fallacy. Any one accustomed to observe the texture of soils, and familiar with the conditions which go to constitute "good tilth," would see at a glance that neither worm-casts, as such, nor the "thin layer of fine dark-colored earth voided by the worms, with which their burrows are lined," can be classed among soils well suited for the growth of plants. "The burrows are not mere excavations, but may rather be compared with tunnels lined with cement." Again, to use Mr. Darwin's words, worms are omnivorous. They swallow an enormous quantity of earth, out of which they extract any digestible matter which it may contain. They also consume a large number of half-decayed leaves of all kinds, excepting a few which have an unpleasant taste, or are too tough for them. They will also consume fresh leaves, as Mr. Darwin has found by repeated trials, as well as raw and roasted meat, fat, and even dead worms. It has been observed, moreover, by naturalists, that worms sometimes drag down into their holes the ends of young, flexible leaves, such as those of grass or grain, in spite of their being firmly attached to the plants.

THEIR ACTION IN THE SOIL.

Mr. Darwin describes the production of worm-casts as follows:

"A worm, after swallowing earth, whether for making its burrow or for food, soon comes to the surface (or to any convenient cavity in the soil) to empty its body. The ejected earth is thoroughly mingled with the intestinal secretions, and is thus rendered viscid. After being dried, it sets hard." . . . "Freshly ejected castings," he says, "often reminded me of the appearance of paint which has just been ground between two flat stones." That is to say, the ejected earth has been so thoroughly "kneaded," "worked," and "puddled" within the bodies of the worms, that it has come to resemble in some sort, as regards its temper and consistence, the prepared clay with which the potter forms his vessels, or that with which the engineer makes the bottoms of reservoirs water tight. Such puddled earth, so long as it remains in the puddled condition, is manifestly unsuited for the growth of plants, and the more of it that is brought into contact with plant roots, so much the worse for the plant. But if the earth-worms can work so rapidly that, as Mr. Darwin shows, it is no uncommon thing in England for them to bring up fine earth to the surface to the extent that a layer as much as one-fifth of an inch in thickness is formed annually at the surface during long terms of years, it is plain that they can puddle no small amount of soil in a single season. "There is good evidence," Mr. Darwin urges, "that on each acre of land, which is sufficiently damp and not too sandy, gravelly, or rocky for worms to inhabit, a weight of more than ten tons of dry earth annually passes through their bodies, and is brought to the surface. So that the whole superficial bed of vegetable mould passes through their bodies in the course of every few years."

In view of the facts that field crops have to struggle with many adverse circumstances at the best, and that, in the generality of cases, they are less carefully protected, fed, and watered, than potted plants, it is not impossible that each one of the 53,000 worms in the three and a half millions pounds of soil on an acre (taken as one foot deep), may do almost as much harm as the single worm in the single flower-pot of the florist. It is probable, of course, that in the field some particular places and plants will be more hardly beset with worms than others, and that the damage done in these places will be proportionally large. Not only the puddling of the earth which passes through the worm, but the mere compaction of the soil caused by the worm pushing his way through it, like a wedge, as he burrows about, is hurtful to good tilth; and so is the adhesive lining of the burrows already alluded to. The overwhelming excess of mere earth, in the worm-casts, makes it plain, withal, that the minute proportion of useful dung or urine constituents really contained in them cannot be counted upon as likely to help a crop to any appreciable extent.

In the case of the flower-pot, it is seen that the washing about of the worm-earth when the plant is watered, converts it into a kind of mud which clogs both the pores of the soil and the pores of the rootlets, to the great detriment of the plant. This fine mud is somewhat similar to that familiarly seen in puddles in roads, and is doubtless almost equally unfit for roots to thrive in. In point of fact, florists, by providing "ample drainage," habitually work to counteract the harmful effects of the puddled earth produced by worms. They are commonly at pains to put so many sherds in a pot, before it is filled with loam, that, within reasonable limits, no matter how much mud may be made by worms, the hole in the bottom of the pot shall not be clogged by it. Were it not for the open sub-soil thus provided, it is said that, in case worms are at work in the pot, the hole will often be tightly stopped with the puddled earth, and that, as a consequence, the whole of the earth in the pot will be "drowned," and be made cold and sour. Some greenhousemen, on noticing worm-casts at the surface of the soil, immediately slip off the pot from the ball of earth and roots within it, and pick out the worms; some of which are apt to be found lying against the ball of earth, *i. e.*, between the earth and the sides of the pot. In case a plant continues to suffer, in spite of these palliative measures, a "sure cure" is effected by repotting it, whereby the worms and their eggs are wholly removed. Other devices for combating earth worms in flower-pots are to apply lime water or mustard water, or to place poisoned bits of potato upon the surface of the earth. Perhaps bits of onion, of cabbage leaves, or celery would be better suited than potato for this service, to judge from Mr. Darwin's remarks on the fondness of worms for these substances. In field practice, it has been reckoned as one advantage of liming land that worms are destroyed by the operation. Salt has also been recommended for destroying worms, and it is probable that heavy dressings of wood ashes would be effective. It is worthy of study whether several of the so-called chemical fertilizers may not be useful in this sense. There is some ground for believing, for example, that many worms might be destroyed by means of high grade superphosphate of lime, especially if it were applied with direct reference to their destruction.

DO THEY EAT THE ROOTS OF PLANTS?

I am myself ignorant as to whether earth-worms ever eat the roots of growing plants, though it is fair to suppose they may do so in some cases. Mr. Darwin finds, for example, that—besides celery, carrots, horseradish, etc., etc.—cabbage leaves and pieces of onion are devoured with much relish by worms; and that even when buried a quarter of an inch deep in common garden soil they were always discovered by the worms upon which he experimented. But if the worms are thus attracted by the odor of pieces of onion, it seems not unreasonable to suppose that they may be attracted in like manner by the growing bulb (or by the rootlets attached to it), which would assuredly be tender enough for their consumption at some period, at least, in early youth. With respect to bulbs, it so happens that I have myself been asked several times by lady friends, how to make callas grow when there were earth-worms in the pot; and it seems not improbable that, in spite of their bitterness, the softness of the calla rootlets may make them attractive to the worms. Although Mr. Darwin makes no mention of potatoes, it is plain from the general drift of his observations that pieces of potato would be acceptable food to earth-worms, and that, in the field, the tubers must be liable to be eaten when they are planted in cut pieces, as is customary nowadays. The old notion that earth worms eat potatoes may perhaps be justified by the damage caused by them at the planting season.

In conversation with practical men, I find there is a diversity of opinion among them as to whether earth-worms ever eat live roots in flower-pots. Some florists maintain that the finer, fibrous roots are actually often eaten by earth-worms, while others hold a contrary opinion. I have heard it said that the worms do no harm by removing earth from about the roots; and, again, "the worms give the plant no rest;" and some observers have noticed that roots are occasionally broken in two by the worms, as they force their way through the earth. In general, however, it appears that the puddling and muddying of the soil is a greater and a more palpable grievance to florists than any actual gnawing of any part of the plants. How much harm may be caused by the acidity of the casts, as observed by Mr. Darwin, is a point still to be determined.

CONCLUSION.—THEIR INCREASE IN NEW ENGLAND.

In listening to the complaints of practical men, and looking at the matter from the economical agricultural point of view, it is not easy to escape the conviction that worms must be decidedly hurtful, especially if account be taken of a single crop, or series of crops, or of any other particular year by itself; and this conviction is but strengthened and verified by the evidence adduced by naturalists as to the magnitude of the work done by the worms, and as to its great geological importance in some countries. It is possible, of course, in field practice, that in certain cases the introduction of some puddled earth may be beneficial to such soils, for instance, as are naturally too open and which stand in need of a binding element. But this supposition can rarely, if ever, be true of really fertile soils, the particles of which almost always need to be made loose and open, by appropriate tillage, rather than to be cemented to the condition of clods. Upon arable soils in good tilth, the scattering of the worm earth upon the surface, by the action of rain or wind, can hardly fail to be hurtful; both because the mud which results from it in rainy weather must tend to clog the pores of the soil, and because such mud in drying would naturally help form a crust at the surface of the land.

It is worthy of remark that the opinion as to the utility of earth-worms advanced by White and others, does not well consist with the familiar fact that these worms were extremely rare, or perhaps altogether absent, in Northern New England, at least, when this country was first settled. As Mr. Marsh, writing in 1863, has well stated, "worms were so scarce forty or fifty years ago in the newer parts of New England, that the rustic fishermen of every village kept secret the few places where they were found in their neighborhood, as a professional mystery." I can myself testify, from personal observation at the northern end of Lake Winipiseogee, in New Hampshire, in the years 1842 and 1846, that, in so far as the boys of that locality knew, there was but one small spot in all the country side where earth-worms could be found. This locality was in the back yard and kitchen garden of one of the houses in the village, to which, as we boys supposed, the worm had been introduced from some other settlement. It hardly needs to be said that the country in question was more fertile when first cleared, and when worms were absent, than it ever has been since. There would seem to be little need, moreover, of urging the self-evident proposition that leaves can decay, and a highly fertile soil be formed, without the intervention of earth-worms. So far from the worms being economically useful in agriculture, it might well be urged that their advent has probably been one cause of the diminution of fertility which is known to have occurred in most places in this country. It seems plain, at all events, that the worms may work to cause sterility, both by destroying dead organic matter (leaves, etc.), which would be valuable if it were left to decay unmolested; by puddling the soil and so impairing its power of supporting vegetation, and as Mr. Darwin himself deems probable, by destroying the low organisms which are essential for the formation of nitrates, and whose presence in good soils is doubtless one prime cause of the fertility. As an extension of this idea, it is not impossible that the absence of the destroying worms may be a necessary condition for the highly interesting and probably useful formation of bicarbonate of lime in dry loams, to which I called attention several years since in one of the numbers of the Bussey Bulletin.

Harvard University, Mass. F. H. STORER.

ON MANURE PHOSPHATE.

By K. WALTER, Chemical Engineer, Auvelais, Belgium.

WHEN I wrote my last article on this subject in the *Chemical News*, vol. xxxviii., pp. 37–50, I could not have imagined that it would take such a long time before the analysis of those phospates by the method of citrate of ammonia would be generally adopted. The more, as I know, that the greater number of English agricultural chemists are convinced that the phosphoric acid soluble in the citrate is equal in value to the phosphoric acid soluble in water.

Professor Petermann, in Gembloux, Chief Manager of the Belgian Royal Agricultural Stations, had in 1877 officially announced that from January 1, 1878, all the phosphoric acid soluble in the citrate of ammonia would be counted at the same rate as the former soluble in water. In short, any sample of superphosphate would no more be valued on its contents of phosphoric acid soluble in water, but only on its contents of phosphoric acid soluble in the citrate of ammonia. To this latter process was then given the term determination of *assimilable* phosphoric acid.

Neither manure manufacturers nor agriculturists made the slightest objection to this innovation, because everybody found himself well off by it; and to-day it has so much become the custom, that neither party appears to think that it has ever been otherwise. The more so, as the repeated trials of latter years have clearly shown the superiority of precipitated phosphate (retrograded phosphate) to the superphosphate. All the experiences of Toulie, Grandeau, Petermann, and many others, are, by the trials of late, confirmed to evidence.

As soon as the decision of Dr. Petermann was known, the German superphosphate manufacturers took up the matter, and tried with all their might to introduce the same system into Germany; but they found it not as easy as they had a right to believe. There were some eminent agricultural chemists who were perfectly of the same opinion as Petermann, and fought by word and writing for the same cause; but the greater number of them, including some of the most influential, were thoroughly against it.

The German Professors never could pardon Petermann, that he had taken, as one of them (Petermann in German), such a measure without first having demanded and obtained the high permission and assent of united sage agricultural Germany.

However, some of them were honest enough to begin to try the matter by experience, and at this period, even the most inveterate opponents of Petermann's system were obliged to come over. It was generally admitted that the phosphoric acid soluble in the citrate has at least the same value as phosphoric acid soluble in water, *for those kinds of soils in which the experiments were made*. They concluded that further experiments must show if the equality is evident in all kinds of soils.

Anyhow this was a great step forward—by which German superphosphate makers have profited. They have begun to count the phosphoric acid soluble in citrate—*en attendant*—at half the price, as that soluble in water. There can, however, not be the slightest doubt that in a time very near to come, the same system as used in Belgium and in France will be adopted in Germany; at all events, manure makers there do their utmost to bring things to this solution.

It is altogether inexplicable that the English manure manufacturers—by far the most interested in this question—did not take serious steps to follow the same road. The quantities of superphosphate made by the English works is so very important that those manufactured on the Continent are a mere nothing against it. The English superphosphate manufactory loses annually hundreds of thousands of pounds by persisting in their present system—and this in times in which the chemical trade cannot afford to make any superfluous losses which easily might be avoided.

Every experienced superphosphate maker knows that even the purest raw phosphates (containing only traces of iron and alumina) give superphosphates, which contain three-quarters to 1 per cent. of phosphoric acid not soluble in water but easily in the citrate of ammonia. Most phosphates, however, used for the trade in question, give superphosphates containing in a fresh state $1\frac{1}{2}$ per cent of phosphoric acid not soluble in water but in the citrate. After storing of three to four months' duration, this latter amounts to 2 to 3 per cent., and sometimes even more—of course to the detriment of the phosphoric acid soluble in water.

If we take superphosphate, on an average, as containing 14·5 per cent. phosphoric acid soluble in citrate, or 13 per cent. phosphoric acid soluble in water. $1\frac{1}{2}$ per cent. are lost for the English manufacturer. That is to say for the whole quantity of phosphoric acid rendered soluble for sale and available for agricultural purposes, 10 per cent. A manufacturer making per year 3,000 tons of superphosphate actually loses about £1,200 annually.

It is certainly no advantage for the agricultural chemists to exchange the handy analysis of phosphoric acid soluble in water, against the more complicated and tedious one of phosphoric acid soluble in the citrate.

They were, however, obliged to do it on the Continent, and the English chemists will have to follow, sooner or later. This mode of analysis has now arrived at such a perfection that the results of the different chemists, when they follow the same method, are most satisfactory, and just of the same accordance as the analysis of phosphoric acid soluble in water. In the International Congress of Agricultural Chemists, held at Paris last summer, the manner of analysis was fixed for the rest.

I will now narrate in as few words as possible the comparative results, given by a great series of trials in different parts of Belgium, Germany, and France, between the superphosphate monobasic phosphoric acid and the precipitated (retrograded, gone-back) phosphoric acid, *considered* to be bibasic; the first soluble in water, the second soluble in citrate of ammonia.

1. In heavy clay soils, the phosphoric acid soluble in water has the same effect as phosphoric acid soluble in the citrate, sometimes even a trifle better.
2. In soils rich in humus, limestone soils, slaty soils, the effect of the second is *at least* the same as that of the first.
3. In light, sandy soils, the effect of phosphoric acid soluble in water is surprisingly inferior to that of phosphoric acid soluble in the citrate.

In short terms, the one is worth as much as the other as a *general rule*, but the intelligent farmer will take his choice in consequence of the soils he has to deal with. In the latter years experience has shown that in light, sandy soils, even precipitated phosphate dried at a very high temperature, and in consequence only containing traces of phosphoric acid soluble in the citrate, is by far superior in its action to superphosphate. I have likewise to remark that repeated trials have shown that phosphoric acid as precipitate is a little superior to phosphoric acid as it is in a retrograded state in the superphosphates, though both are soluble in the citrate. I attribute this difference in action to the different mechanical state of them, the precipitate permitting a finer division in the soil. The reason why monobasic phosphoric acid has in the most kinds of soils an action inferior to that one of bibasic phosphoric acid is easy to explain. In heavy clay soils, the first one, the monobasic phosphoric acid, is put into solution by the water contained in the ground rather quickly, but is fixed immediately through the propensity of such soils to retain all kinds of salt solutions mechanically, and this in a very powerful manner. By and by it is transformed by the limestone, iron, or alumina in the ground into bibasic phosphate of lime, iron, or alumina; and as such it is by slow degrees, according to the want of the plants, again put into solution by the carbonic acid, certain salt solutions, and even by the secretion of the roots themselves. The bibasic phosphate has not to be transformed and is ready for action.

In light and sandy soils, the superphosphate is more or less lost; those soils, not having a very strong fining power, the rain washes its solution right through into the subsoil, before it has time to transform itself into bibasic phosphate. This latter, however, put into the ground as such is only—being slowly soluble—put to profit by and by, just as the plants wanted it during their growth.

The consequence of those observations has been that phosphoric acid in the precipitate of lime is already paid at a little higher rate than phosphoric acid in the superphosphate in Belgium and the north of France. The demand far exceeds the production of the former.

The enormous loss of the English superphosphate makers is not the only drawback in this important question; a great

resource of the English chemical manufacturing industry is likewise cut off by maintaining the present system. In England are actually great quantities of *muriatic acid* runing to waste, not to count those enormous quantities which are employed for bleach making. This latter article stands at present at a price which makes it hardly worth while to manufacture it, and many works use hydrochloric acid only for that purpose, because they are not allowed to let the acid run away.

England has equally great layers of natural phosphates, too poor to be employed for superphosphate making, but they are just the thing to serve as raw material for the manufacturing of precipitated phosphate, by means of the now useless quantities of muriatic acid. With the progress this kind of manufacture has made in the latter years, it would be an exceedingly profitable one in England.

Of course, as long as precipitated phosphate has to be exported to bring its real value, no manufacturer will find it inviting enough to go in for it, though even for export it would very well be worth while to manufacture it; and once tried in England by some farmers it would make its way in no time, even if chemists and superphosphate makers cannot *as yet* make up their minds to introduce officially the citrate of ammonia analysis.

May these few lines tend to direct the attention of the leading chemical men and manufacturers in England to the important question before named, and cause them to take serious and united steps for the welfare of the English chemical trade by following a system now in application for the past four years on the Continent.

CULTIVATION OF THE RAMIE PLANT.

THE ramie plant possesses qualities and merits of the highest value for textile industries, and in the whole of Europe. Consul Stanton states that France alone has attempted the industrial development of this Chinese plant, and the attempt has met with such success as to give that country a decided advantage over other European manufacturing countries. At the present time the cultivation makes great progress in Southern France, Corsica, and Algiers, and a practical process has lately been discovered for separating the fibers from the stems. The plant belongs to the nettle family, and although stingless, is similar to the stinging nettle in the form both of its leaves and branches, having, however, a much more luxuriant growth. The branches grow straight and in bunches, and are composed of a brittle woody substance, filled with pith, and surrounded with a fibrous covering, which, in its turn, is covered with a thin skin or rind. The fibers are bound together by a resinous substance, which is more difficult to dissolve than that contained in flax and hemp, and from this circumstance the setting of the ramie plant is more laborious than hemp and flax, though the hackling of the stems is less arduous. The propagation of the plant may be affected by seeds, layers, or cuttings; but as the reproduction from seeds is generally slow and uncertain, slips and layers are more often used. The ramie is a perennial, and not like flax or hemp, an annual, and its strength and fertility increases with its age. It withstands both drought and damp, but is very susceptible to frost. Even after frost, however, it is only the first crop which is lost, since the roots, which penetrate the ground to a depth of about a foot, are seldom affected, and soon put forth new shoots. Its growth is unusually rapid, and even in France it attains annually a height of from six feet to eight feet. In its home, however (China and Bengal), it attains the height of fifteen feet. By cutting the stems when they have attained a height of three feet, several crops and finer fibers are obtained, the plant renewing its shoots continually. The leaves, when dried, are valuable for the manufacture of the tough paper which is so extensively used in China, while the green ones afford excellent cattle fodder. On account of its luxuriant growth, extensive manuring is requisite; and, with the exception of this manuring, and the careful manner in which it must be done, the cultivation of the ramie is of the simplest kind, and with due care for frost, it may be planted at any season. The planting is generally in furrows ten inches deep, and a yard apart, the plants being set out at intervals of a yard. Hoeing and digging are only necessary the first year, the plant growing afterwards with such luxuriance as to smother all weeds. In the spring, and after each cutting, hoeing is generally resorted to; and if at the approach of winter, the earth is heaped round the roots, to protect them from frost, the branches increase rapidly in number, the first growth yielding from three to four, the second from six to eight, the third from ten to twelve, and the fourth (this, however, is only in warm climates), from sixteen to twenty branches. The pecuniary results so far obtained are most satisfactory. It is maintained that the ramie plant will yield a crop worth from £56 to £80 per hectare (2·47 acres); and assuming that three cuttings are annually obtained, there would be a yield of from 4,000 to 5,000 kilos of leaves alone, which would cover all the expenses of cultivation. In addition to this, there would be from 1,500 to 2,200 kilos of fibers, from which 1,200 to 1,500 kilos of white linen could be spun. The tenacity of the ramie fiber is 30 per cent. greater than that of flax, and in consequence of this tenacity it has for many years been used in China, in the manufacture of many articles in which solidity is absolutely necessary. In China, from fibers of this plant the coarsest nets are woven, and fabrics which surpass in gloss and delicacy the finest battiste. As with flax and hemp, the first operation is to separate the fibers from the resinous substance which unites them. This is effected by steeping in water. The Belgians have recently substituted for the old plan a new, more rapid, and healthier process, which produces an excellent commercial result. Large square cemented vats are used. In these the branches are laid, then water is poured on, and kept for flax and hemp, for one or two days, and for ramie from five to six days. To the water one-half per cent. of the weight of the branches of pulverized charcoal is added, and the same quantity of carbonate of soda of potash, and throughout the process the vats are kept carefully closed. In this manner decomposition takes place slowly, and the fibers are protected from the injurious effects of the exhalations of sulphureted hydrogen. After the gluten is dissolved from the fibers they have only to be separated from the woody tissue. This is effected by hackling, which was formerly slowly and arduously done by hand, but is now performed by machinery in a very simple manner. The branches are passed successively through four pairs of rollers, which destroy the woody tissue; then the hackling is done by two pairs of grooved cylinders, which, by a movement backwards and forwards, rub and cleanse the fibers from all impurities. A third machine, which consists of a hollow cylinder inclosing an axle, does the combing. This axle is provided with a number of whips, which beat the fibers continually. The fibers enter the cylinder at an opening in the side, the dust is removed by a ventilator, and the branches, reduced to the finest fiber, leave the machine perfectly cleansed, and after bleaching are ready for spinning. In consequence of the silky character of the fiber it is necessary to fasten the warp securely, to prevent its being pulled out when weaving. Special attention is also paid to the dyeing, to insure fast colors. In France, measures have been taken for the manufacture of elegant ramie stuffs on a large scale, either from ramie for tablecloths and furniture coverings, or mixed for wool and silk for draperies; and it is the opinion of those engaged in the manufacture of textile fabrics that the time has arrived when this material will play a great *role* in textile industries.—*Textile Manufacturer.*

HYACINTH BULBS.

By GRANT ALLEN.

IF we were not so familiar with the fact, we would think there were few queerer things in nature than the mode of growth followed by this sprouting hyacinth bulb on my mantelpiece here. It is simply stuck in a glass stand, filled with water, and there, with little aid from light or sunshine, it goes through its whole development like a piece of organic clockwork, as it is, running down slowly in its own appointed course. For a bulb does not grow as an ordinary plant grows, solely by means of carbon derived from the air under the influence of sunlight. What we call its growth we ought rather to call its unfolding. It contains within itself everything that is necessary for its own vital processes. Even if I were to cover it up entirely, or put it in a warm, dark room, it would sprout and unfold itself in exactly the same way as it does here in the diffused light of my study. The leaves, it is true, would be blanched and almost colorless, but the flowers would be just as brilliantly blue as those which are now scenting the whole room with their delicious fragrance. The question is, then, how can the hyacinth thus live and grow without the apparent aid of sunlight, on which all vegetation is ultimately based?

Of course, an ordinary plant, as everybody knows, derives all its energy or motive power from the sun. The green leaf is the organ upon which the rays act. In its cells the waves of light propagated from the sun fall upon the carbonic acid which the leaves drink in from the air, and by their disintegrating power liberate the oxygen while setting free the carbon, to form the fuel and food-stuff of the plant. Side by side with this operation the plant performs another, by building up the carbon thus obtained into new combinations with the hydrogen obtained from its watery sap. From these two elements the chief constituents of the vegetable tissues are made up. Now the fact that they have been freed from the oxygen with which they are generally combined gives them energy, as the physicists call it, and when they re-combine with oxygen, this energy is again given out as heat, or motion. In burning a piece of wood or a lump of coal, we are simply causing the oxygen to re-combine with these energetic vegetable substances, and the result is that we get once more the carbonic acid and water with which we started. But we all know that such burning yields not only heat, but also visible motion. This motion is clearly seen even in the draught of an ordinary chimney, and may be much more distinctly recognized in such a machine as the steam-engine.

At first sight, all this seems to have very little connection with hyacinth bulbs. Yet, if we look a little deeper into the question, we shall see that a bulb and an engine have really a great many points in common. Let us glance first at a somewhat simpler case, that of a seed, such as a pea or a grain of wheat. Here we have a little sack of starches and albumen laid as nutriment for a sprouting plantlet. These rich food stuffs were elaborated in the leaves of the parent pea, or in the tall haulms of the growing corn. They were carried by the sap into the ripening fruit, and there, through one of those bits of vital mechanism which we do not yet completely understand, they were selected and laid by in the young seed. When the pea or the grain of wheat begins to germinate, under the influence of warmth and moisture, a very slow combustion really takes place. Oxygen from the air combines gradually with the food stuffs or fuels—call them which you will—contained in the seed. Thus heat is evolved, which in some cases can be easily measured with the thermometer, and felt by the naked hand—as, for example, in the malting of barley. At the same time motion is produced; and this motion, taking place in certain regular directions, results in what we call the growth of a young plant. In different seeds this growth takes different forms, but in all alike the central mechanical principle is the same: certain cells are raised visibly above the surface of the earth, and the motive power which so raised them is the energy set free by the combination of oxygen with their starches and albumens. Of course, here, too, carbonic acid and water are the final products of the slow combustion. The whole process is closely akin to the hatching of an egg into a living chicken. But, as soon as the young plant has used up all the material laid by for it by its mother, it is compelled to feed itself just as much as the chicken when it emerges from the shell. The plant does this by unfolding its leaves to the sunlight, and so begins to assimilate fresh compounds of hydrogen and carbon on its own account.

Now it makes a great deal of difference to a sprouting seed whether it is well or ill provided with such stored-up food-stuffs. Some very small seeds have hardly any provisions to go on upon; and the seedlings of these, of course, must wither up and die if they do not catch the sunlight as soon as they have first unfolded their tiny leaflets; but other wiser plants have learnt by experience to lay by plenty of starches, oils, or other useful materials in their seeds; and wherever such a tendency has once faintly appeared, it has given such an advantage to the species where it occurred, that it has been increased and developed from generation to generation through natural selection. Now what such plants do for their offspring, the hyacinth, and many others, like it, do for themselves. The lily family, at least in the temperate regions, seldom grows into a tree-like form; but many of them have acquired a habit which enables them to live on almost as well as trees from season to season, though their leaves die down completely with each recurring winter. If you cut open a hyacinth bulb, or, what is simpler to experiment upon, an onion, you will find that it consists of several short abortive leaves, or thick fleshy scales. In these subterranean leaves the plant stores up the food-stuffs elaborated by its green portions during the summer: and there they lie the whole winter through, ready to send up a flowering stem early in the succeeding spring. The material in the old bulb is used in thus producing leaves and blossoms at the beginning of the second or third season; but fresh bulbs grow out anew from its side, and in these the plant once more stores up fresh material for the succeeding year's growth.

The hyacinths which we keep in glasses on our mantelpieces represent such a reserve of three or four years' accumulation. They have purposely been prevented from flowering, in order to make them produce finer trusses of bloom when they are at length permitted to follow their own free will. Thus the bulb contains material enough to send up leaves and blossoms from its own resources; and it will do so even if grown entirely in the dark. In that case the leaves will be pale yellow or faintly greenish, because the true green pigment, which is the active agent of digestion, can only be produced under the influence of light; whereas the flowers will retain their proper color, because their pigment is always due to oxidation alone, and is but little dependent upon the ways of sunshine. Even if grown in an ordinary room, away from the window, the leaves seldom assume their proper deep tone of full green; they are mainly dependent on the food-stuffs laid by in the bulb, and do but little active work on their own account. After the hyacinth has flowered, the bulb is reduced to an empty and flaccid mass of watery brown scales.

Among all the lily kind, such devices for storing up useful material, either in bulbs or in the very similar organs known as corms, are extremely common. As a consequence, many of them produce unusually large and showy flowers. Even among our native English lilies we can boast of such beautiful blossoms as the fritillary, the wild hyacinth, the meadow-saffron, and the two pretty squills; while in our gardens the tiger lilies, tulips, tuberoses, and many others belong to the same handsome bulbous group. Closely-allied families give us the bulb-bearing narcissus, daffodil, snow-drop, amaryllis, and Guernsey lily; the crocus, gladiolus, iris, and corn-flag; while the neighboring tribe of orchids, most of which have tubers, probably produce more ornamental flowers than any other family of plants in the whole world. Among a widely-different group we get other herbs which lay by rich stores of starch, or similar nutritious substances, in thickened underground branches, known as tubers; such, for example, are the potato and the Jerusalem artichoke. Sometimes the root itself is the storehouse for the accumulated food-stuffs, as in the dahlia, the carrot, the radish, and the turnip. In all these cases, the plant obviously derives benefit from the habit which it has acquired of hiding away its reserve fund beneath the ground, where it is much less likely to be discovered and eaten by its animal foes. For it is obvious that these special reservoirs of energetic material, which the plant intends as food for its own flower or for its future offspring, are exactly those parts which animals will be likely unfairly to appropriate to their personal use. What feeds a plant will feed a squirrel, a mouse, a pig, or a man, just as well. Each requires just the same free elements, whose combination with oxygen may yield it heat and movement. Thus it happens that the parts of plants which we human beings mainly use as food stuffs are just the organs where starch has been laid by for the plant's own domestic economy—seeds, as in the pea, bean, wheat, maise, barley, rice, or millet; tubers, as in the potato and Jerusalem artichoke; corms, as in the yam or tare; and roots, as in arrowroot, turnip, parsnip, and carrot. In all these, and in many other cases, the habit first set up by nature has been sedulously encouraged and increased by man's deliberate selection. What man thus consciously effects in a few generations, the survival of the fittest has unconsciously effected through many long previous ages of native development.—*Knowledge.*

A SHEEP-EATING PARROT.

A SINGULAR bird has recently been added to the collection in the Zoological Gardens, London. This is none other than a carnivorous parrot, whose love of animal flesh manifests itself in a very decided predilection for mutton. There are two things which to the naturalist are remarkable in connection with this bird. First, it is, in respect of this flesh eating propensity, an exception to the whole family of parrots, which are frugivorous, living on fruits, seeds, leaves, buds, and the like; and second, this carnivorous taste is not a natural but an acquired possession, the species of parrot in question having been till a few years since frugivorous, like others of its family.

This curious bird is the kea (*Nestor notabilis*) or mountain parrot, and comes from New Zealand. The general color of its plumage is green; its length from point of bill to extremity of tail is twenty one inches; its bill is about two inches long, the upper mandible being curved, and very strong. It inhabits the higher wooded glens and recesses of the mountainous districts of New Zealand, and, like the owl, is generally nocturnal in its habits. The kea was first made known to science in 1856. In the time of Maori rule, the bird was as innocent and harmless in its habits, as respects its food, as any others of the parrot family; and it was not till the higher tracts of country were utilized by the early settlers as runs for sheep, that the kea was tempted to desert its fruit-eating habits, and to join the destructive army of the carnivora.

About 1868, it was noticed at the sheep-shearing season on the upland runs that many sheep were suffering from sores or scars, more or less recent, on the back, immediately in front of the hips. Curiously enough, it was observed that in all the animals so injured the wound was in precisely the same place in each—fairly above the kidneys. In some cases (says Mr. Potts, who has contributed an article to the *Zoologist* on the subject), the part affected had a hard dry scab or merely a patch of wool stripped off; others showed a severe wound, in some instances so deep that the entrails protruded. The animals so injured were invariably those that were in the best condition; and many discussions ensued as to what could be the cause of this singular state of things. At last a shepherd gave it as his opinion that the injury was inflicted by a kind of parrot, rather a tame sort of bird, that was to be met with in the higher ranges; but the shepherd's opinion was only laughed at. Yet the shepherd, after all, was found to be right. In connection with the stations on sheep-runs in New Zealand, there is a meat-gallows, where the carcasses of sheep killed for food are kept; and it was observed by the shepherds that the keas were in the habit of visiting the gallows and breaking off bits of mutton-fat with their strong beaks. Soon afterward, one or more hands actually saw a parrot on the back of a sheep plucking and tearing the wool and flesh on a precisely similar spot to that where so many had been found to be fatally wounded.

There was no doubt about the keas being the offenders, and means were at once taken to have their numbers reduced. Since then, a mortal enmity has existed against them on the part of the shepherds; and justly so, as it is found that from three to five per cent. of every flock is so wounded or killed. In some individual instances, the ratio of destruction has been much higher. On one station on the Matatapu, out of a flock of twenty Lincoln rams, nineteen were within

THE ANTIQUITIES OF YUCATAN.

1. Bust of the Princess Nicte-Canchi.—2. Hieroglyphic inscription.—3. The god Chaacmol.—4. Grand salon of the ancient Government Palace at Uxmal.

one month killed by these parrots. On another run, a flock of three hundred and ten strong young wethers were, within a period of five months, so seriously injured by the keas, that at the end of that time only one hundred and five remained alive. In consequence of this destruction, men were engaged to kill the bird at a shilling a head; and these men, taking advantage of its nocturnal habits, now range the mountains at night, lighting fires to attract their game. In the daytime, they rest and prepare the skins for sale. But the kea, with the cleverness and cunning of its tribe, has grown very shy and wary, and knows very well, when it sees a man carrying a gun, what he is likely to do with it.

Mr. Potts gives a striking account of the cruelty and rapacity of the keas in the prosecution of their horrible taste for sheep-fat, the part especially liked by them being the fat that surrounds the kidneys. With this view, they do not hesitate to tear open the animal's flesh till they arrive at these organs, after tearing out the fat of which they leave the poor animal to linger on or die in excruciating agony. "Sheep," says Mr. Potts, "while being got out of snow-drifts, are often mortally hurt by the attacks of keas; especially are the birds prone to molest those carrying double fleeces, as though they knew how firm a foothold they could maintain with their gripe. When one of these sheep, temporarily exhausted with its exertions in toiling through deep snow under the burden of two years' growth of wool, breaks off from the mob and leaves the track, desperately floundering into deeper snow-wreaths, a flock of parrots, ever watchful as they hover round, soon perceive their opportunity for mischief; they alight close to the spot where the sheep, unconscious of approaching danger, stands gazing fixedly in a state of helpless stupidity; gradually hopping or moving toward the victim with some show of caution, one of the keas at last settles on the back of the sheep, which, terrified at the strange visitor that thus besets it, bounds away; the bird now rises only to alight again on the same place, and clutching into the wool with its sharp claws, retains its hold more firmly and tenaciously. In vain the tortured animal in the direst agony seeks to rid itself of its cruel persecutor that boldly keeps its vantage; after running and struggling some distance, its efforts to escape become feebler; it is at length so hard pressed that in a few minutes it yields passively to the tearing and searching beak of the kea."

These repulsive flesh-devouring propensities may have been acquired through the bird being forced, in severe winters, to approach the stations in hopes of finding food, and there feeding on the flesh in the meat-gallows, and thus gradually forming a carnivorous appetite of such strength that its former frugivorous tastes are entirely destroyed, and flesh now forms its sole food. The kea in the Zoological Gardens was struck down while it was in the act of attacking a sheep; but the man did not succeed in capturing it till it had torn his clothes in many places and severely lacerated his hands. Its food consists mainly of mutton, raw; it does not care for cooked meat, but will take it if very hungry. Occasionally it will take beef, and is fond of pork. But its vegetarian tastes seem almost completely eradicated, for it will not touch bread, though it likes the seed of sow-thistle. It is altogether a remarkable and curious bird.

THE MONUMENTS AND INSCRIPTIONS OF AMERICAN HISTORY.

WHAT especially characterizes the state of barbarism among a people is the ignorance of that art so indispensable to civilization—*writing*. It was believed for a long time that, before the discovery of America by Columbus, the indigenous races possessed no graphic system worthy of the name, and that for recalling to mind important facts the aborigines were unable to trace anything more than paintings or mnemonic images. The celebrated Humboldt maintained such an opinion, and asserted that nowhere in the New World before the arrival of the European conquerors had there been invented a means of writing texts capable of being read.

On the one hand an ancient MS. of a former bishop of Yucatan, Diego de Landra, and on the other, the great works of Leon de Rosny on the deciphering of the inscriptions found in Yucatan, permit us to-day to assert that the old continent not only knew the art of writing, but had made use of it for many centuries. Since the publication of these works the attention of Americans has more than ever been directed to this region, which promises to make the New World rank even in its remotest ages among the most civilized countries of the earth. Several intrepid explorers have visited the region of the isthmus and undertaken researches that have been followed by results of great importance.

It is usually thought that Peru and ancient Mexico were the two principal centers of civilization in America previous to the memorable age of Ferdinand and Isabella; but such is not the case. It was not in these countries that the greatest material and intellectual progress was made in ancient times, but in the zone that serves in some sort as a bond of union between Peru and Mexico—the tongue of land which separates the Atlantic from the Pacific ocean.

It is, in fact, in the small republics of Guatemala, San Salvador, Costa Rica, Honduras, and especially in the Yucatan peninsula that are found the most astonishing vestiges of the indigenous art of the New World, as well as those written texts that have permitted the science called *Americanism* by the French to rehabilitate, quite recently, a portion of our globe that had hitherto been considered rude, barbarous, and nearly semi-savage before the arrival of the Europeans in the fifteenth century.

The publication in 1841 of the travels of John L. Stephens to Chiapas and Yucatan gave the first idea of the civilization that flourished in Central America before the arrival of Cortez; and since that period several other travelers have in their turn given the same glowing account as Mr. Stephens of the magnificence of the architecture in the Yucatan peninsula. But all this was insufficient to awaken the attention of the learned on the subject of American antiquity; and to do this it was necessary to establish the fact, not only that there was an indigenous writing in Yucatan, but that there existed in such writing numerous inscriptions and even true manuscript books. These books and these inscriptions, which are accumulating every day, will eventually form a new literature in which we shall find the old Indians recounting to us themselves their history, making known to us their system of religion, and describing to us from their point of view all the great evolutions of intelligence in the world, so little known, of the red race.

The question has been discussed for a long time in the American Society at Paris whether these civilized peoples of Central America had reached a certain ideal in point of art. The monstrous form of some of their plastic representations has caused them to be judged at times with extreme severity, and one savant has gone so far as to maintain the somewhat paradoxical opinion that they had succeeded in obtaining *the ideal of ugliness!* Such an accusation cannot be hereafter sustained. With the exception of those of Greece and Rome, artists in all parts of the world have been found reproducing by the chisel fantastic figures which responded much less to their intellectual status than to the need of satisfying the popular ideas of their time and surroundings. The images of certain Yucatan and Mexican divinities do, it must be confessed, possess something of the horrible and repulsive; but, alongside of these aberrations of the Indian genius, we find also sculptures that are as remarkable for the exactness of their proportions as for their purity of trait and happy expression of sentiment. The monuments of this kind are, it is true, relatively quite rare; but new ones are gradually being discovered, and the moment has not yet come in which it is allowable to pronounce with certainty and definiteness on the artistic merits of the red race.

Among travelers who have since explored Central America, must be cited Dr. Le Plongeon, who, with his wife, established himself for several years in Yucatan, where he devoted himself to researches in the less known parts of the peninsula, and Mr. Charnay, who has just accomplished in this same country a great scientific mission.

We have already given, in SUPPLEMENT No. 316, figures of several monuments of antiquity found in Yucatan, and which give a good idea of the style of architecture that was in vogue there at an epoch which preceded the arrival of the celebrated Genoese in the archipelago of the Antilles. In the engravings given opposite are shown still further specimens of ancient American art.

The bust of Nicte-Canchi, daughter of the founder of Uxmal, reproduced among these figures from a photograph by Mr. and Mrs. Le Plongeon, and the statue of Chaacmol, her brother, presented by these travelers to the Mexican Museum, serve as examples of Yucatanesque statuary, but can not be considered as the most beautiful examples of this art. The work of Mr. Stephens, above-mentioned, presents us with obelisks wherein the talent of the artist has shown itself in a manner evidently superior and not less original.

Until the sacred writing of this country has been completely interpreted it will not be possible to form an exact idea of the progress effected by the Indians before they came in communication with the Europeans. The date to which the antiquity of their history extends back is still extremely uncertain. The Abbé Brasseur, of Bourbourg, puts it at nine thousand years. Mr. de Rosny considers is as extending back hardly more than six centuries previous to the Christian era. Unfortunately the deciphering of the hieroglyphic writing of Yucatan will necessarily be accomplished very slowly unless some unexpected discovery should happen to modify the conditions under which it has been undertaken. Nothing like the resources possessed by Champollion for deciphering the hieroglyphics of Egypt exists for aiding us to understand the enigmatic characters of Central America, and everything here must be worked out by means of comparisons and paleographic processes of exceeding delicacy. The very nature of the Yucatanesque writing was uncertain; but Mr. de Rosny has succeeded in determining the characters accurately and to the satisfaction of competent judges. He has been enabled to re-establish by the old manuscripts all the elements of the indigenous cycle, to explain several religious ceremonies which are represented therein, to considerably enrich the catalogue of known signs, and to read with certainty a certain number of words.

It is henceforth merely a question of time when we shall be able to prosecute the study of the ancient American literature as that of the ancient basin of the Nile and of the Euphrates is being done. The discoveries of the daring travelers who are at present exploring Central America will greatly contribute to bridge over the difficulties.

THE DESERT OF SAHARA.

IN a paper which Dr. Oscar Lenz contributes to the *Zeitschrift* of the Berlin Geographical Society, he gives an authentic account of the results of his journey across the Sahara, from Tanger to Timbuktu, and thence to Senegambia. The real journey was begun at Marrakesh, at the northern foot of the Atlas Mountains, where Dr. Lenz laid in his stores of provisions and changed his name and dress, traveling further under the disguise of a Turkish military surgeon. He crossed the Atlas and the Anti-Atlas in a south-western direction. The Atlas consists, first, of a series of low hills belonging to the Tertiary and Cretaceous formations, then of a wide plateau of red sandstone, probably Triassic, and of the chief range which consists of clay-slates with extensive iron ores. The pass of Bibauan is 1,250 meters above the sea-level, and it is surrounded with peaks about 4,000 meters high, while the Wadi Sus Valley at its foot is but 150 meters above the sea. The Anti-Atlas consists of Paleozoic strata. On May 5, 1880, Dr. Lenz reached Tenduf, a small town founded some thirty years ago, and promising to acquire great importance as a station for caravans. The northern part of the Sahara is a plateau 400 meters high, consisting of horizontal Devonian strata, which contain numerous fossils. On May 15 Dr. Lenz crossed the moving sand-dunes of Igidi, a wide tract where he observed the interesting phenomenon of musical sand, a sound like that of a trumpet being produced by the friction of the small grains of quartz. But amidst these moving dunes it is not uncommon to find some grazing places for camels, as well as flocks of gazelles and antelopes. At El Eglab Dr. Lenz found granite and porphyry, and was fortunate enough to have rain. Thence the character of the desert becomes more varied, the routes crossing sometimes sandy and sometimes stony tracts or sand-dunes, with several dry river-beds running east and west between them. On May 29 he reached the salt works of Taudeni, and visited the ruins of a very ancient town, where numerous stone implements have been found. Here he crossed a depression of the desert only 145 to 170 meters high, while the remainder of the desert usually reaches as much as 250 to 300 meters above the sea-level; and he remarks that throughout his journey he did not meet with depressions below the sea-level. The schemes for flooding the Sahara are therefore hopeless and misleading. The landscape remained the same until the wide Alfa fields, which extend north of Arauan. This little town is situated amidst sand-dunes devoid of vegetation, owing to the hot southern winds. Four days later Dr. Lenz was in Timbuktu, whence he proceeded west to St. Louis. During his forty-three days' travel through the Sahara, Dr. Lenz observed that the temperature was not excessive; it usually was from 34° to 36° Celsius, and only in the Igidi region it reached 45°. The wind blew mostly from the north-west, and it was only south of Taudeni that the traveler experienced the hot south winds (*edrash*) of the desert. As to the theory of the north-eastern trade-winds being the cause of the formation of the desert, Dr. Lenz remarks that he never observed such a wind, nor did his men; it must be stopped by the hilly tracts of the north. Another important remark of Dr. Lenz is what he makes with respect to the frequent description of the Sahara as a sea-bed. Of course it was under the sea, but during the Devonian, Cretaceous, and Tertiary periods; as to the sand which covers it now, it has nothing to do with the sea: it is the product of destruction of sandstones by atmospheric agencies. Northern Africa was not always a desert, and the causes of its being so now must be sought for not in geological but in meteorological influences.

A GLIMPSE THROUGH THE CORRIDORS OF TIME.*

By Prof. ROBERT S. BALL.

YOUR committee has done me much honor by inviting me to deliver the first lecture in this large and very beautiful hall. In accepting the task I was aware that it involved a great responsibility, but I had various grounds of encouragement. I remembered that I was not coming among you as a stranger, and I knew that I had a subject worthy of a memorable occasion. I would I were equally confident of my ability to do justice to so noble a theme.

The lecture bears the somewhat poetical title of "A Glimpse through the Corridors of Time." A poetic title has been chosen, because if I can properly exhibit the subject you will see that it appeals powerfully to the imagination as well as to the reason. I shall invite you to use your imagination to aid in looking back into the very remotest recesses of antiquity. And when I speak of antiquity I do not mean the paltry centuries with which our historians have to deal. The ancient days to which I refer are vastly anterior to those of the "grand old masters" and those of the "bards sublime." Nor do we even allude to the thousands of years which have elapsed since Babylon and Nineveh were splendid and populous cities. Even the noble pyramids of Egypt are but of yesterday when compared with the æons of years which must pass before our review.

The most ancient human monuments that now exist cannot, I suppose, be more than a few thousand years old. Five thousand years nearly exhausts all historical time. Ten thousand years certainly does. Though we have no earlier historical record, yet other records are not wanting. Geology tells us that ten thousand years is but a mere moment in the span of the earth's history. We learn from geology that even the career of man himself has lasted far more than ten thousand years. Yet man is but the latest addition to the succession of life on the earth. For the chronology of the earlier epochs of the earth's history we require majestic units to give adequate expression to our dates. Thousands of years are not sufficient, nor tens of thousands, nor hundreds of thousands. The course of geological time is to be reckoned in millions of years.

The corridors of time through which I wish to give you a glimpse are these dignified millions. Yet our retrospect will only extend to a certain definite epoch in the past history of our earth. We speak of nothing anterior to the time when our earth assumed the dignity of maternity, and brought forth its first and only child. We shall trace the development of that child, which, though millions of years old, is still in dependence on its parent. We shall describe the influence of the parent over the child, and the not less remarkable reaction of the child upon the parent. We shall foreshadow the destiny which still awaits the mother and child when millions of years shall have elapsed.

At the time of its birth the earth was not as we see it now, clothed with vegetation and teeming with animal life. It was a huge inorganic mass, too hot for life, perhaps hot enough to be soft or viscid, if not actually molten. The offspring was what might be expected from such a parent. It was also a rude inorganic mass. Time has wrought wondrous changes in both parent and child. Time has transformed the earth into an abode of organic life. It has transformed the earth's offspring into our silvery moon.

It will be my duty to sketch for you the manner in which these changes have been brought about. To a great extent we can do this with no hesitating steps; we are guided by a light which cannot deceive. It is the light of mathematical reasoning. These discoveries are of an astronomical character, but they have not been made by telescopes. They have been made by diligent labors of the most abstruse kind. The mathematical astronomer sits at his desk, and not in an observatory. He has in his hand a pen and not a telescope. Before him lies a sheet of paper and not the starry heavens. He is no doubt furnished with a few facts from observation. It is his province to interpret those facts, to inform them with life, and to infer the unknown from the known. It is thus discoveries are made which are the sublimest efforts of human genius.

The argument on which I invite you to follow me is founded on a very simple matter. Many of those present go every summer to the seaside. Those who do so are well acquainted with the daily ebb and flow which we call the tides. Even the children with their spades and buckets know how the flowing tide will fill their moats dug in the sand and inundate their mimic castles. In the ebb and flow of the tide we have a mechanical engine of mighty power. I hope this evening to point out the wonderful effect which tides have had on the earth in times past, as well as the effect they will exercise in the future. It is the tides which are to reveal to us a glimpse through the Corridors of Time.

The cause of the ebb and flow of the tide has long ceased to be a mystery. In the earliest times it was noticed that the tides were connected with the moon. Pliny and Aristotle both refer to the alliance between the tides and the age of the moon. It is well known that the tides on our coasts sometimes rise to an unusual height. Those who dwell on low ground adjoining tidal rivers are painfully aware of this fact by the floods which are often produced. Such occurrences generally take place at the time of new moon or of full moon. At first quarter or last quarter the tides are even below the usual height. A fisherman who has to regulate his movements by the tides will know full well that at certain times the tides rise higher and fall lower than at other times. He brings his boat out on the falling tide, he brings it back on the rising tide, and when making the harbor after a night's fishing, it would be natural to hear him say: "Oh, we shall run in easily this morning, there is a strong tide, moon was full last night." Or if he had to cross a dangerous bank he would soon learn the difference between the spring tide and the neap. Fishermen are not much addicted to abstract reasoning. For many centuries, perhaps, indeed, for

* Lecture delivered at the Midland Institute, Birmingham, on October 24, 1881, by Prof. Robert S. Ball, LL.D., F.R.S., Andrews Professor of Astronomy in the University of Dublin, and Royal Astronomer of Ireland. Contributed by the Author.

thousands of years, observant men might have known that the moon and the tides were connected. But they did not know any reason why this connection should exist. I dare say they did not even know whether the moon was the cause of the tides or the tides the cause of the moon.

Nor is it easy to explain the tides. We were all taught that the moon makes the tides. Yet I can imagine an objector to say: "If the moon makes the tides, why does it give Bristol a splendid tide of forty feet, while London is put off with only eighteen?" The true answer is that the height of the tide is largely affected by local circumstances, by the outline of the coasts, by estuaries and channels. It is even affected to some extent by the wind. Into such details, however, I do not now enter; all I require is that you shall admit that the moon causes the tides, and that the tides cause currents. In some few places the currents caused by the tides are made to do useful work. A large reservoir is filled by the rising tide, and as the water enters it turns a water wheel. On the ebbing tide the water flows out of the reservoir, and again gives motion to a water wheel. There is here a source of power, but it is only in very exceptional circumstances that such a contrivance can be worked economically. Sir W. Thomson, in his address to Section A of the British Association at York, went into this question in its commercial aspect. At present, however, we may say that the power of the tides is as much wasted as is the power of Niagara. Perhaps when coal becomes more scarce, and when the means of distributing power by electricity are more developed, the tides and the great waterfalls will be utilized; but that day will not be reached while coal is only a few shillings a ton.

Though we have not yet put the tides into harness, yet tides are not idle. Work they will do, whether useful or not. In some places the tidal currents are scouring out river channels; in others they are moving sand banks. From a scientific point of view the work done by the tides is of unspeakable importance. To realize the importance, let us ask the question: Whence is this energy derived with which the tides do their work? The answer seems a very obvious one. If the tides are caused by the moon, the energy they possess must also be derived from the moon. This looks plain enough, but unfortunately it is not true. Would it be true to assert that the finger of the rifleman which pulls the trigger supplies the energy with which the rifle bullet is animated? Of course it would not. The energy is derived from the explosion of the gunpowder, and the pulling of the trigger is merely the means by which that energy is liberated. In a somewhat similar manner the tidal wave produced by the moon is the means whereby a part of the energy stored in the earth is compelled to expend itself in work. I do not say this is an obvious result. Indeed it depends upon a refined dynamical theorem, which it would be impossible to enter into here.

But what do we mean by taking energy from the earth? Let me illustrate this by a comparison between the earth rotating on its axis and the fly-wheel of an engine. The fly-wheel is a sort of reservoir, into which the engine pours its power at each stroke of the piston. The various machines in the mill merely draw off the power from the store accumulated in the fly-wheel. The earth is like a gigantic fly-wheel detached from the engine, though still connected with the machines in the mill. In that mighty fly-wheel a stupendous quantity of energy is stored up, and a stupendous quantity of energy would be given out before that fly wheel would come to rest. The earth's rotation is the reservoir from whence the tides draw the energy they require for doing work. Hence it is that though the tides are caused by the moon, yet whenever they require energy they draw on the supply ready to hand in the rotation of the earth.

The earth differs from the fly-wheel of the engine in a very important point. As the energy is withdrawn from the fly-wheel by the machines in the mill, so it is restored thereto by the power of the steam engine, and the fly runs uniformly. But the earth is merely the fly wheel without the engine. When the work done by the tides withdraws energy from the earth, that energy is never restored. It therefore follows that the energy of the earth's rotation must be decreasing. This leads to a consequence of the most wonderful importance. It tells us that the speed with which the earth rotates on its axis is diminishing. We can state the result in a manner which has the merits of simplicity and brevity.

"The tides are increasing the length of the day."

This statement is the text of the discourse which I am to give you this evening. From this simple fact the new and wondrous theory of tidal evolution is deduced. A great scientific theory is generally the outcome of many minds. To a certain extent this is true of the theory of tidal evolution. It was Prof. Helmholtz who first appealed to what tides had already done on the moon. It was Prof. Purser who took an important step in the analytical theory. It was Sir William Thomson's mathematical genius which laid the broad and deep foundations of the fabric. These are the pioneers in this splendid research. But they were only the pioneers. The great theory itself is chiefly the work of one man. You are all familiar with the name he bears. The discoverer of tidal evolution is Mr. G. H. Darwin, Fellow of Trinity College, Cambridge.

It would be impracticable for me now to go into the actual mathematical calculations. I shall rather endeavor to give you an outline of this theory, shorn of its technical symbols. I think this can be done, even though we attempt to retain the accuracy of mathematical language. Nor would it be fair to throw on Mr. Darwin or the other mathematicians I have named the responsibility for all I am going to say. I must be myself responsible for the way in which those theories are set forth, as well as for some of the deductions made from them.

At present no doubt the effect of the tides in changing the length of the day is very small. A day now is not appreciably longer than a day a hundred years ago. Even in a thousand years the change in the length of the day is only a fraction of a second. But the importance arises from the fact that the change, slow though it is, lies always in one direction. The day is continually increasing. In millions of years the accumulated effect becomes not only appreciable but even of startling magnitude.

The change in the length of the day must involve a corresponding change in the motion of the moon. This is by no means obvious. It depends upon an elaborate mathematical theorem. I cannot attempt to prove this for you, but I think I can state the result so that it can be understood without the proof. If the moon acts on the earth and retards the rotation of the earth, so, conversely, does the earth react upon the moon. The earth is tormented by the moon, so it strives to drive away its persecutor. At present the moon revolves round the earth at a distance of about two hundred and forty thousand miles. The reaction of the earth tends to increase that distance, and to force the moon to revolve in an orbit which is continually getting larger and larger.

Here then we have two remarkable consequences of the tides which are inseparably connected. Remember also that we are not enunciating any mere speculative doctrine. These results are the inevitable consequences of the tides. If the earth had no seas or oceans, no lakes or rivers; if it were an absolutely rigid solid throughout its entire mass, then these changes could not take place. The length of the day would never alter, and the distance of the moon would only fluctuate between narrow limits.

As thousands of years roll on, the length of the day increases second by second, and the distance of the moon increases mile by mile. These changes are never reversed. It is the old story of the perpetual dropping. As the perpetual dropping wears away the stone, so the perpetual action of the tides has sculptured out the earth and moon. Still the action of the tides continues. To-day is longer than yesterday; yesterday is longer than the day before. A million years ago the day probably contained some minutes less than our present day of twenty-four hours. Our retrospect does not halt here; we at once project our view back to an incredibly remote epoch which was a crisis in the history of our system.

Let me say at once that there is great uncertainty about the date of that crisis. It must have been at least fifty millions years ago. It may have been very much earlier. This crisis was the interesting occasion when the moon was born. I wish I could chronicle the event with perfect accuracy, but I cannot be sure of anything except that it was more than fifty millions years ago.

I do not admit that there is anything discreditable about this uncertainty. Do you not know that our historians who have records and monuments to help them, are often in great confusion about dates? I am not going to find any fault with historians. They do their best to learn the truth; but I cannot help reminding you that they are often as much in the dark about centuries as the astronomers are about millions. Take, for example, the siege of Troy, which Homer has immortalized, and ask the historians to state the date of that event. Some say that the siege of Troy was 1184 B.C., others that it was 900 B.C.: both are equally uncertain. Schliemann says that he found the remains of the town burned down, but that no one knows who did it or when it was done. Others, again, say that there was never any siege of Troy at all.

A recent instance which has attracted great and deserved attention is Schliemann's discovery at Mycenæ of what he considers to have been the tomb of Agamemnon. The tomb certainly did contain the remains of some mighty man, if we may judge by the hundred-pound weight of gold ornaments which were found there. Most people think that these tombs, whosoever they were, date from at least 1000 B.C. On the other hand, some very high authorities regard the monuments as the tombs of northern invaders who came into Greece 500–600 A.D. Here then we have a range of some fifteen hundred years for the date of the tombs, and no dates between these two are possible. I am sure I do not pretend to decide between them, or even to have an opinion on the subject; but I cannot help saying that in one respect the astronomers are better off than the historians. The historians cannot even agree whether Schliemann's gold ornaments are B.C. or A.D. Astronomers are, at all events, certain that the date of the moon's birth was before the present era.

At the critical epoch to which our retrospect extends, the length of the day was only a very few hours. I cannot tell you exactly how many hours. It seems, however, to have been more than two and less than four. If we call it three hours we shall not be far from the truth. Perhaps you may think that if we looked back to a still earlier epoch, the day would become still less and finally disappear altogether! This is, however, not the case. The day can never have been much less than three hours in the present order of things. Everybody knows that the earth is not a sphere, but that there is a protuberance at the equator, so that, as our school books tell us, the earth is shaped like an orange. It is well known that this protuberance is due to the rotation of the earth on its axis, by which the equatorial parts bulge out by centrifugal force. The quicker the earth rotates the greater is the protuberance. If, however, the rate of rotation exceeds a certain limit the equatorial portions of the earth could no longer cling together. The attraction which unites them would be overcome by centrifugal force and a general break up would occur. It can be shown that the rotation of the earth when on the point of rupture corresponds to a length of the day somewhere about the critical value of three hours, which we have already adopted. It is therefore impossible for us to suppose a day much shorter than three hours. What occurred prior to this I do not here discuss.

Let us leave the earth for a few minutes, and examine the past history of the moon. We have seen the moon revolves around the earth in an ever-widening orbit, and consequently the moon must in ancient times have been nearer the earth than it is now. No doubt the change is slow. There is not much difference between the orbit of the moon a thousand years ago and the orbit in which the moon is now moving.

But when we rise to millions of years the difference becomes very appreciable. Thirty or forty millions of years ago the moon was much closer to the earth than it is at present; very possibly the moon was then only half its present distance. We must, however, look still earlier, to a certain epoch not less than fifty millions of years ago. At that epoch the moon must have been so close to the earth that the two bodies were almost touching. I dare say this striking result will come upon many with surprise when they hear it for the first time. It was, I know, with great surprise that I myself read of it not many months ago. But the evidence is unimpeachable, and it is indeed wonderful to see how such information has been gained by merely looking at the ripples of the tide.

Everybody knows that the moon revolves now around the earth in a period of twenty seven days. The period depends upon the distance between the earth and the moon. The time and the distance are connected together by one of Kepler's celebrated laws, so that, as the distance shortens, so must the time of revolution shorten. In earlier times the month must have been shorter than our present month. Some millions of years ago the moon completed its journey in a week instead of taking twenty-eight days, as at present. Looking back earlier still, we find the month has dwindled down to a day, then down to a few hours, until at that wondrous epoch when the moon was almost touching the earth, the moon spun round the earth once every three hours.

It would require the combined powers of a poet and a mathematician to portray the scene with becoming dignity. I have only promised to give you that glimpse along the Corridors of Time which I have myself been able to obtain. The scene is laid in the abyss of space; the time is more than fifty millions years ago; the *dramatis personæ* are the earth and the moon.

In those ancient times I see our earth to be a noble globe, as it is at present. Yet it is not partly covered with oceans and partly clothed with verdure. The primeval earth seems rather a fiery and half-molten mass, where no organic life can dwell. Instead of the atmosphere which we now have, I see a dense mass of vapors in which, perhaps, all the oceans of the earth are suspended as clouds. I see that the sun still rises and sets to give the succession of day and night, but the day and the night together only amount to three hours instead of twenty-four. Almost touching this chaotic mass of the earth is another much smaller and equally chaotic body. Around the earth I see this small body rapidly rotating. The two revolve together as if they were bound by invisible bands. This smaller body is the moon. Such is the picture which I wish to present to you as a Glimpse through the Corridors of Time.

I have hitherto refrained from introducing any merely speculative matters. If we can believe anything of mathematics, anything of dynamics, we must admit that the picture I have attempted to outline is a faithful portrait. The only uncertain elements are the date and the periodic time. I do, however, now propose to venture on one speculation in which Mr. Darwin has indulged. I propose to offer a suggestion as to how a small body came into this most remarkable position close by the earth, and how its motion was produced.

We have hitherto been guided by the unerring light of dynamics, but at this momentous epoch dynamics deserts us, and we have only probability to guide our faltering steps. One hint, however, dynamics does give. It reminds us that a rotation once in three hours is very close to the quickest rotation which the earth could have without falling to pieces. As the earth was thus predisposed to rupture, it is of extreme interest to observe that a cause tending to precipitate such a rupture was then ready to hand. It seems not unlikely that we are indebted to the sun as the occasion by which the moon was fractured off from the earth and assumed the dignity of an independent body. It must be remembered that the sun produces tides in the earth as well as the moon, but the solar tides are so small compared with the lunar tides, that we have hitherto been enabled to neglect them. There could, however, have been no lunar tides before the moon existed, and consequently in the early ages before the moon was detached, the earth was disturbed by the solar tides, and by the solar tides alone.

The primeval earth thus rose and fell under the tidal action of the sun. Probably there were no oceans then on the earth; but tides do not require oceans or even water for their operation. The primitive tides were manifested as throbs in the actual body of the earth itself, which was then in a more or less fluid condition. Even at this moment, bodily tides are disturbing the solid earth beneath our feet; but these tides are now so small as to be imperceptible when compared with the oceanic tides.

At the remote epoch of which we are speaking the solar tides were very small, as they are at present. Yet, small as they are, there was a particular circumstance which may have enormously increased their importance. The point to which I refer can be illustrated very simply. We have here a weight of 14 lb. freely suspended, and here I have a small wooden mallet which barely weighs half an ounce, yet small as this mallet is, I can make the heavy weight swing by merely giving it blows with the mallet. Let me try. I give the weight blow after blow. I hit it as hard as I can, yet the weight hardly swings. I have not yet been successful. The art of succeeding is merely to time the blows properly; this I am now doing, and you see the weight swings in an arc which is steadily augmenting.

We therefore see that a succession of impulses, in themselves small, can yet produce a great effect when they are properly timed. In the present case the impulses should succeed each other at the same interval as this pendulum requires for one to and fro oscillation. The time therefore depends on the body struck, and not at all on the body which gives the impulses.

Just as this pendulum swings with a definite period, so the vibrations of the primeval earth had a certain period appropriate to them. Suppose that the liquid primeval globe were pressed in on two quadrants and drawn out on the two others, and that the pressures were then released. The globe would attempt to regain its original form, but this it could not do at once, any more than the pendulum can at once regain its vertical position; the protruded portions would go in, but they would overshoot the mark, and the globe would thus oscillate to and fro. Now it has been shown that the period of such oscillations in our primitive globe is about an hour and a half, or very close to half the supposed length of the day at that time. The solar tides, however, also have a period half the length of the day. Here then we have a case precisely analogous to the fourteen-pound weight I have just experimented on. We have a succession of small impulses given which are timed to harmonize with the natural vibrations. Just as the small timed impulses raised a large vibration in the weight, so the small solar tides on the earth threw the earth into a large vibration. At first these vibrations were small, but at each succeeding impulse the amplitude was augmented, until at length the cohesion of the molten matter could no longer resist; a separation took place; one portion consolidated to form our present earth; the other portion consolidated to form the moon.

There is no doubt whatever that the moon was once quite close to the earth; but we have to speculate as to what brought the moon into that position. I have given you what I believe to be the most reasonable explanation, and I commend it to your attention. There are difficulties about it, no doubt; let me glance at one of them.

I can easily imagine an objector to say: "If the moon were merely a fragment torn off, how can we conceive that it should have that beautiful globular form which we now see? Ought not the moon to have rugged corners and an irregular shape? and ought not the earth to show a frightful scar at the spot where so large a portion of its mass was rent off?"

You must remember that in those early times the earth was not the rigid solid mass on which we now stand. The earth was then so hot as to be partially soft, if not actually molten. If then a fragment were detached from the earth, that fragment would be a soft yielding mass. Not for long would that fragment retain an irregular form; the mutual attraction of the particles would draw the mass together. By the same gentle ministrations the wound on the earth would soon be healed. In the lapse of time the earth would become as whole as ever, and at last it would not retain even a scar to testify to the mighty catastrophe.

I am quite sure that in so large and so cultivated an audience as that which I am now addressing, there are many

persons who take a deep interest in the great science of geology. I believe, however, that the geologist who had studied all the text-books in existence might still be unacquainted with the very modern researches which I am attempting to set forth. Yet it seems to me that the geologists must quickly take heed of these researches. They have the most startling and important bearing on the prevailing creeds in geology. One of the principal creeds they absolutely demolish.

I suppose the most read book that has ever been written on geology is Sir Charles Lyell's "Principles." The feature which characterizes Lyell's work is expressed in the title of the book, "Modern Changes of the Earth and its Inhabitants Considered as Illustrative of Geology." Lyell shows how the changes now going on in the earth have in course of time produced great effects. He points out triumphantly that there is no need of supposing mighty deluges and frightful earthquakes to account for the main facts of geology.

Lyell attempts to show that the present action of winds and storms, of rains and rivers, of ice and snow, of waves and tides, will account for the formation of strata, and that the gentle oscillations of the earth's crust will explain the varying distribution of land and water. In this we can to a great extent follow him. I am quite satisfied with the oscillations in the land. If the land rises an inch or two every century in one place and falls to the same extent elsewhere, all that is required has been explained. Nor do I feel at present disposed to question his views as to rivers or to glaciers, to rains or to winds. There is, however, one great natural agent of which Lyell does not take adequate account. He does not attach enough importance to the tides. No doubt he admits that the tides do some geological work. He even thinks they can do a great deal of work. The sea batters the cliffs on the coasts, and wears them into sand and pebbles. The glaciers grind down the mountains, the rains and frosts wear the land into mud, and rivers carry that mud into the sea. In the calm depths of ocean this mud subsides to the bottom; it becomes consolidated into rocks; in the course of time these rocks again become raised, to form the dry land with which we are acquainted.

The tides, says Lyell, help in this work. Tidal currents aid in carrying the mud out to sea; they aid to a considerable extent in the actual work of degradation, and thus contribute their quota to the manufacture of stratified rocks. Such is the modest *role* which Lyell has assigned to the tides, and no doubt the majority of geologists have acquiesced in this doctrine. Nor can there be any doubt that this is a just view of tidal action at present. That it is a just view of tidal action in past times is what I now deny. Lyell did not know—Lyell could not have known—that our tides are but the feeble surviving ripples of mighty tides with which our oceans once pulsated. Introduce these mighty tides among our geological agents, and see how waves and storms, rivers and glaciers, will hide their diminished heads.

I must attempt to illustrate this view of tidal importance in ancient geological times. Let me try by the aid of the tides to explain the great difficulty which every one must have felt in regard to Lyell's theory. I allude to the stupendous thickness of the Paleozoic rocks.

Look back through the Corridors of Time in the manner in which they are presented to us in the successive epochs of geology. We pass rapidly over the brief career of prehistoric man; then through the long ages of tertiary rocks, when the great mammals were developed; back again to the much earlier period when colossal reptiles and birds were the chief inhabitants of the earth; back again to those still earlier ages when the luxuriant forests flourished that have given birth to the coal fields; back once more to the age of fishes; back finally to those earliest periods when the lowest forms of life began to dawn in the paleozoic era.

As we date remote ages astronomically by the distance of the moon, so we date remote ages geologically by the prevailing organic life. It is a great desideratum to harmonize these two chronological systems, and to find out, if possible, what lunar distance corresponds to each geological epoch. In the whole field of natural science there is no more noble problem. Take, for example, that earliest and most interesting epoch when life perhaps commenced on the earth, and when stratified rocks were deposited five or ten miles thick, which seem to have contained no living forms higher than the humble eozoon, if even that were an organized being. Let us ask what the distance of the moon was at the time when those stupendous beds of sediment were deposited in the primeval ocean. We have in this comparison every element of uncertainty except one. The exception is, however, all important. We know that the moon must have been nearer to the earth than it is at present. There are many very weighty reasons for supposing that the moon must have been very much nearer than it is now. It is not at all unlikely that the moon may then have been situated at only a small fraction of its present distance. My argument is only modified, but not destroyed, whatever fraction we may take. We must take some estimate for the purpose of illustration. I have had considerable doubts what estimate to adopt. I am desirous of making my argument strong enough, but I do not want to make it seem exaggerated. At present the moon is two hundred and forty thousand miles away; but there was a time when the moon was only one-sixth part of this, or say forty thousand miles away. That time must have corresponded to some geological epoch. It may have been earlier than the time when the eozoon lived. It is more likely to have been later. I want to point out that when the moon was only forty thousand miles away, we had in it a geological engine of transcendent power.

On the primitive oceans the moon raised tides as it does at present; but the forty-thousand-mile moon was a far more efficient tide producer than our two-hundred-and-forty-thousand-mile moon. The nearer the moon the greater the tide. To express the relation accurately, we say that the efficiency of the moon in producing tides varies inversely as the cube of its distance. Here then we have the means of calculating the tidal efficiency for any moon distance. The forty-thousand-mile moon being at a distance of only one-sixth of our present moon's distance, its tidal efficiency would be increased $6 \times 6 \times 6$ fold. In other words, when our moon was only forty thousand miles away, it was two hundred and sixteen times as good a tide producer as it is at present.

The heights to which the tides rise and fall is so profoundly modified by the coasts and by the depth of the sea, that at present we find at different localities tides of only a few inches and tides of sixty or seventy feet. In ancient times there were no doubt also great varieties in the tidal heights owing to local circumstances. To continue our calculation, we must take some present tide. Let us discard the extremes just indicated and take a moderate tide of three feet rise and three feet fall as a type of our present tides. On this supposition what is to be a typical example of a tide raised by the forty-thousand-mile moon? If the present tides be three feet, and if the early tides be two hundred and sixteen times their present amount, then it is plain that the ancient tides must have been six hundred and forty-eight feet.

There can be no doubt that in ancient times tides of this amount and even tides very much larger must have occurred. I ask the geologists to take account of these facts, and to consider the effect—a tidal rise and fall of six hundred and forty-eight feet twice every day. Dwell for one moment on the sublime spectacle of a tide of six hundred and forty-eight feet high, and see what an agent it would be for the performance of geological work! We are now standing, I suppose, some five hundred feet above the level of the sea. The sea is a good many miles from Birmingham, yet if the rise and fall at the coasts were six hundred and forty-eight feet, Birmingham might be as great a seaport as Liverpool. Three-quarters tide would bring the sea into the streets of Birmingham. At high tide there would be about one hundred and fifty feet of blue water over our heads. Every house would be covered, and the tops of a few chimneys would alone indicate the site of the town.

In a few hours more the whole of this vast flood would have retreated. Not only would it leave England high and dry, but probably the Straits of Dover would be drained, and perhaps even Ireland would in a literal sense become a member of the United Kingdom. A few hours pass, and the whole of England is again inundated, but only again to be abandoned.

These mighty tides are the gift which astronomers have now made to the working machinery of the geologist. They constitute an engine of terrific power to aid in the great work of geology. What would the puny efforts of water in other ways accomplish when compared with these majestic tides and the great currents they produce?

In the great primeval tides will probably be found the explanation of what has long been a reproach to geology. The early paleozoic rocks form a stupendous mass of ocean-made beds which, according to Professor Williamson, are twenty miles thick up to the top of the silurian beds. It has long been a difficulty to conceive how such a gigantic quantity of material could have been ground up and deposited at the bottom of the sea. The geologists said: "The rivers and other agents of the present day will do it if you give them time enough." But unfortunately the mathematicians and the natural philosophers would not give them time enough, and they ordered the geologists to "hurry up their phenomena." The mathematicians had other reasons for believing that the earth could not have been so old as the geologists demanded. Now, however, the mathematicians have discovered the new and stupendous tidal grinding-engine. With this powerful aid the geologists can get through their work in a reasonable period of time, and the geologists and the mathematicians may be reconciled.

I have here a large globe to represent the earth, and a small globe suspended by a string to represent the moon. At the commencement of the history the two globes were quite close; they were revolving rapidly, and the moon was constantly over the same locality on the primeval earth. I do not know where that locality was; it was probably the part of the earth from which the moon had been detached. No doubt it was somewhere near the equator, but the distinction of land and water had not then arisen. Around the primeval earth the moon revolved in three hours; the earth also revolved in three hours, so that the moon constantly remained over the red region. This I can illustrate by holding the small globe which represents the moon in one hand, and making the large globe, which represents the earth, revolve by the other.

This state of things formed what is known as unstable dynamical equilibrium. It could not last. Either the moon must fall back again on the earth, and be reabsorbed into its mass, or the moon must commence to move away from the earth. Which of these two courses was the moon to take? The case is analogous to that of a needle balanced on its point. The needle must fall some way, but what is to decide whether it shall fall to the right or to the left? I do not know what decided the moon, but what the decision was is perfectly plain. The fact that the moon exists shows that it did not return to the earth, but that the moon adopted the other course, and commenced its outward journey.

As the moon recedes, the period which it requires for a journey round the earth increases also. Initially that period was but three hours, and it has increased up until our present month of 656 hours.

The rotation of the earth has been modified by the retreat of the moon. Directly the moon began to retreat the earth was no longer under an obligation to keep the same face thereto. When the moon was at a certain distance the earth made two rotations for every revolution that the moon made. Thus as I carry the small globe round the large globe the latter makes two revolutions for one revolution of the small globe. Still the moon gets further and further away, until the earth performs three, four, or more rotations for each of the moon's revolutions. Do not infer that the rate of the earth's rotation is increasing; the contrary is the fact. The earth's rotation is getting slower, and so is that of the moon; but the retardation of the moon is much greater than that of the earth. Even though the rotation of the earth is much more than the primitive three hours, yet that of the moon has increased to several times the rotation of the earth.

The moon recedes still further and further, and at length a noticeable epoch is reached to which I must call attention. At that epoch the moon is so far out that its revolution takes twenty-nine times as long as the rotation of the earth. The month was then twenty-nine times the day. The duration of the day was less than the present twenty-four hours, but I do not believe it was very much less. The time we are speaking of is not very remote, perhaps only a very few million years ago. The month was then in the zenith of its glory. The month was never twenty-nine times as long as the day before. It has never been twenty-nine times as long as the day since. It will never be twenty-nine times as long as the day again.

Resuming our history, we find the moon still continuing to revolve in an ever-widening circle, the length of the month and of the day both increasing. The ratio of the day to the month was still undergoing a change. When the moon was a little further off the earth only revolved twenty-eight times instead of twenty-nine times in one revolution of the moon. Still the velocity of the earth abates until it only makes twenty-seven revolutions in one revolution of the moon. This is an epoch of especial interest, for it is the present time. In the present order of things the moon revolves round the earth once while the earth rotates twenty-seven times. This has remained sensibly true for thousands of years, and no doubt will remain sensibly true for thousands of years to come, but it will not remain true indefinitely. Wondrous as are the changes which have occurred in times past, not less wondrous are the changes which are to occur in time to come. The tides have guided our gropings into the past; they will continue to guide our researches to make a forecast of the future.

Further and further will the moon retreat, and more and more slowly will the earth revolve. But we shall not pause at intervening stages; we shall try to sketch the ultimate type to which our system tends. In the dim future, many millions of years distant, the final stage will be approached. As this stage draws nigh, the rotation of the earth will again approach to equality with the revolution of the moon. From the present month of twenty-seven days we shall pass to a month of twenty-six days, of twenty-five days, and so on, until eventually we shall reach a month of two days, and lastly a month of one day. When this state has been attained the earth will constantly turn the same region toward the moon. I do not know what is the locality on the earth which is destined for this distinction.

Here you see that the first state and the last state of the earth-moon history are in one sense identical. In each case the same face of the earth is constantly directed toward the moon. In another way, how different are the first stage and the last! At the beginning the day and the month were both equal, and they were each three hours. At the end the day and the month will be again equal, but they will each be 1,400 hours. The moon will then go round the earth in 1,400 hours, while the earth will rotate on its axis in the same time. In other words, the day is destined in the very remote future to become as long as fifty-seven of our days. This epoch will assuredly come if the universe lasts long enough. When it has come it will endure for countless ages. It would endure for ever if the earth and the moon could be isolated from all external interference.

We heard a great deal a few years ago about the necessity of shortening the hours of labor. I wish to point out that the social reformers who are striving to shorten the hours of labor are pulling one way, while the moon is pulling the other. The moon is increasing the length of the day. The change will be very gradual, but none the less it is inevitable. Where will the nine hours' movement be when the day has increased to fourteen hundred hours? This will be a very serious matter, and there is only one way by which it can be avoided. The question is one rather for engineers than for astronomers; but I cannot help throwing out a suggestion. My advice is: Anchor the moon, and keep it from going out. If you can do this, and if you can also provide a brake by which the speed of the moon can be controlled, then you will be able for ever to revel in the enjoyment of a twenty-four-hour day.

Should this engineering feat never be accomplished, then we have only the fourteen-hundred-hour day to look forward to. Nor is there anything untoward in the prospect, when we take natural selection as our comforter. By natural selection man has become exactly harmonized with his present environment. No doubt natural selection moves at a dignified pace, but so in all truth does tidal evolution. Natural selection and tidal evolution have advanced *pari passu* through all the past millions of geological time. They will advance *pari passu* through all the ages yet to come. As the day lengthens, so will man's nature gradually change too, without any hardship or inconvenience. All that is necessary is plenty of time. Should we think it a hardship that our children should have a day of twenty-four hours and one second instead of twenty-four hours? That the day enjoyed by our grandchildren should be a second longer than the day of our children? That the day of our great-grandchildren should be a second longer still, and so on continually? This would be no inconvenience whatever. No one except the astronomers would be able to detect the change, and daily life would be unaltered. Yet, carry on this process for only one hundred and fifty million years, and we shall find that the whole change of the day from twenty-four hours to fourteen hundred hours has been accomplished. The actual rate of change is indeed much less than this, and is at present so small that astronomers can hardly even detect it.

Our remote posterity will have a night 700 hours long, and when the sun rises in the morning 700 hours more will elapse before he can set. This they will find a most suitable and agreeable arrangement. They will look back on our short periods of rest and short periods of work with mingled curiosity and pity. Perhaps they will even have exhibitions of eccentric individuals able to sleep for eight hours, work for eight hours, and play for eight hours. They will look on such curiosities in the same way as we look on the man who undertakes to walk a thousand miles in a thousand hours.

I am beyond all things anxious to give you the impression that I am not indulging in any mere romance. No doubt the various figures I have mentioned are but estimates. They may be found to require correction—perhaps large correction; but the general outline of the theory must be true. Should any traces of doubt still linger in the mind of some prejudiced person, let me finally dissipate them. Perhaps some caviler may say: Where are the proofs of all this action of the tides? How do you know that the tides are sufficiently powerful to produce such changes? I believe I have shown this abundantly, but some people require a great deal of conviction. I have therefore kept my best argument for the end.

For an overwhelming proof of tidal efficiency I shall summon the heavens themselves to witness, and I shall point to the stupendous task which tides have already accomplished. As the moon has made and is making tides on the earth, so the earth once raised tides on the moon. These tides have ceased for ages; their work is done; but they have raised a monument in the moon to testify to the tidal sufferings which the moon has undergone. To that monument I now confidently appeal. The moon being much smaller than the earth, the tides on the moon produced by the earth must have been many times as great as the tides on our earth produced by the moon. It matters not that the moon now contains no liquid ocean. Nor does it matter whether the moon ever had a liquid ocean. In very ancient days the moon was not the hard, rigid mass which it now appears. Time was when the volcanoes raged on the moon with a fury which nothing on our earth at present can parallel. The moon was then in a soft or a more or less fluid condition, and in this viscous mass the earth produced great tides.

Great tides in truth they were, for the earth is eighty times as heavy as the moon. On the other hand, the moon is only one-fourth the diameter of the earth; so that the actual height of the tides on the moon would be still many times as great as the tides on the earth. When the moon was nearer to us, as it was in early ages, those tides were still greater. Think for one moment of what a lunar tidal wave of such magnitude would be capable. This wave is perhaps of molten lava; it would tear over the surface with terrific power, and anything that friction could accomplish that great cur-

rent would do. That tidal current has done its work; even if the moon were fluid at the present day it could no longer be distracted by tides. Remember, it is not the mere presence of the tide which produces friction. It is the action of the tide in rising and in falling which accomplishes the work. If, therefore, the moon moved so that it was always high tide at the same place, the tides could produce no further effect. The spot where the tide is high on the moon is the spot which is toward the earth. It hence follows that the action of the tides will cease when the moon constantly directs the same face to the earth. The moon has thus at length gained a haven of rest from a tidal point of view. No doubt the moon has a high tide and it has a low tide, but those tides no longer ebb and flow: The moon has succumbed to the incessant action of friction, and has assumed the only attitude which can relieve it from incessant disturbance.

For many centuries it had been an enigma to astronomers why the moon should always turn the same face to the earth. It could be shown that there were many million chances to one in favor of this being due to some physical cause. The ordinary theory of gravitation failed to explain the cause. Every one had noticed this phenomenon. Yet the explanation was never given till lately. It was Helmholtz who showed that this was a consequence of ancient tides, and this simple and most satisfactory explanation has been universally accepted. The constant face of the moon is a living testimony to the power of the tides. What tides have accomplished on the moon is an earnest of what tides will accomplish on the earth.

In the great conflict of the tides the earth has already conquered the moon, and forced the moon to render perpetual homage as a token of submission. Remember, however, that the earth is large, and the moon is small. Yet small though the moon is, it gallantly struggles on. "You have forced me," cries the moon to the earth, "to abandon the rotation with which I was originally endowed; you have compelled me to rotate in the manner you have dictated. I will have my revenge. It is true I am weak, but I am unrelenting; day by day I am exhausting you by the tides with which I make you throb. The time will assuredly come, though it may not be for millions of years, when you shall be forced to make a compromise. When that compromise is made, the turmoils of the tides will cease; our mutual movements will be adjusted. With equal dignity we shall each rotate around the other; with equal dignity we shall each constantly bend the same face to the other."

There is another point to be considered. We must not forget that there is a sun in the heavens as well as a moon. The sun also produces tides in the earth. Those tides were much smaller than the lunar tides, so that we could afford to neglect them. But we have seen that the lunar tides will gradually decrease to nothing. It behooves us then to consider what the solar tides can effect which shall be worthy of our attention. In a lecture which I gave here some years ago, I made allusion to the discovery of the satellites of Mars. I mentioned that one of the satellites of Mars presented a phenomenon unparalleled in the solar system. The satellite revolved around Mars in a period of seven hours, while Mars himself rotated on his axis in a period of twenty-four hours. We here actually find the moon of Mars rotating around Mars in much less than one of Mars' own days. This was a most curious and unexpected circumstance, but the observations of the discoverer, Asaph Hall, placed the great fact beyond any doubt. The mystery has now been explained. It is due to the action of the solar tides on Mars. Nay more, we can actually foresee that at some incredibly remote future time our earth and moon are destined to present the same movements which have seemed so anomalous in Mars.

Left to themselves, the earth and the moon would have remained for ever in the condition of compromise. The moon would have revolved round the earth in fourteen hundred hours. The earth would have rotated on its axis in fourteen hundred hours also. But now the solar tides intervene. They have little effect upon the moon; it revolves as before, but the solar tides begin to retard the earth still further. Instead of a period of fourteen hundred hours, the earth will have a still longer day, so that finally the moon revolves more rapidly around the earth than the earth rotates on its axis.

It seems to me that the episode I have mentioned is one of the most interesting in the whole of modern astronomy. We have first a most delicate telescopic discovery of the tiny satellite of Mars and of its anomalous movements. We then have a beautiful explanation of how this anomalous motion has arisen from the action of solar tides. Finally we have in this miniature system of Mars a foreshadowing of the ultimate destiny of our earth and our moon.

Do I say the ultimate destiny? Nothing is ultimate in nature. The moon and the earth would have come to an amicable and a final agreement had they been let alone. But now the sun has intervened and disturbed the earth's rotation. The truce once broken, the moon again produces tides on the earth, the earth reacts on the moon, and a whole chain of complicated movements are the consequence. I shall not now attempt to trace the further progress of events.

I have dealt with very large figures in this lecture, and perhaps I have taxed your imagination by my demands that you should conceive of periods of tens of millions of years. Yet after all let us look at the results in their true proportion, compared with the universe in which our lot has been cast.

Truly we have been engaged with a very trifling matter. Is not our earth one of the most insignificant bodies in the universe? And our moon is much smaller still. Nor is it even the life-history of our earth that we have been considering, it is merely a brief episode in that history. What are the periods of time we have been discussing when compared with those infinitely longer periods during which the solar system has been evolved? Even the solar system is but one out of one hundred million such systems, each of which has its own life history. Viewed in their true proportions, the phenomena I have described are but of infinitesimal importance, and the time they have occupied is merely ephemeral.

No doubt we have only dwelt upon the tides on the earth and the tides in the moon, which have been of such infinite importance. But do not suppose that tides are confined to the earth and to the moon. So far as we know, everybody in the universe is capable of producing, and actually does produce, tides in every other body. Every planet throbs in response to the tides produced in it by every other planet. Every star has a distinct tidal wave produced in it by every other star. You may say that such tides are infinitesimal, but you must remember that infinitesimal causes, sufficiently often repeated, can achieve the mightiest effects.

We know that tides have wrought our solar system into its present form; and are we to say that the wondrous powers of the tide have no grander scope for their exercise? I prefer to believe that tides operate far and wide through the universe, and that in the recognition of the supreme importance of tidal evolution we mark a great epoch in the history of physical astronomy.

THE SOUTH CAROLINA PHOSPHATE MINES.

A CORRESPONDENT of the *Times* describes at considerable length the valuable phosphate industry of South Carolina. The phosphate deposits are found in the beds of recent and ancient tidal streams and marshes. The whole of the phosphate region is low; an elevation of 20 feet is rare, while the prevailing level is not more than 10 feet above high-water mark. The phosphate rocks are composed, according to Prof. Francis S. Holmes, of eocene marl, torn off by the action of the waves from the great mass of this formation, and swept inland over the sand-bars (which, as well as the great marl-beds, were at one time covered with water), to be deposited in the saline marshes and salt-water creeks and lakes that now form the phosphatic region of South Carolina. This theory is sustained by the fact that the teeth and bones of the shark, whale, seal, porpoise, etc., are found embedded, and not merely intermingled, as the teeth and bones of land animals are, in the phosphate rock. There is no doubt whatever that there have been great and comparatively rapid changes in the coast line of this region. During its gradual elevation the salt-water bays and lakes became lagoons, frequented by many land animals, whose fæces and remains were added to those brought into the same receptacles from the sea. In time these elements converted the carbonate of lime, constituting the marl masses, into the highly phosphatized nodular rock now mined. The correspondent did not see any land mines of more than 6 feet in depth; the river mines have sometimes a depth of 20 feet of water above them, the phosphate rock at the bottom having a shallow covering of mud or sand over it. The land mines exhibit very slight differences in level, though beds are found underlying hundreds of contiguous acres. The yield of clean, dry rock varies from 300 to 1,200 tons an acre, the average yield of the land beds now worked being from 700 to 800 tons an acre.

The most noticeable feature of the Carolina phosphate is its nodular shape. Even when found in apparently smooth and compact floors, it is nevertheless composed of nodules of egg-like or kidney form. The exterior of these nodules is rough and even honeycombed by irregular cavities as a generality, though they are also found of smooth and compact shapes. The nodules vary greatly in size; some are less than an inch, some are several feet, in diameter. Their weight is, of course, as variable; it is anything from a ton downward. In the mass, the rock has frequently a shining or enameled appearance, its color being a grayish-white in the land mines and a gray or bluish-black in the river mines, and it is so porous that it can absorb from 5 to 15 per cent. of water when hot-air dried. When the phosphate nodules are freshly dug they emit, under friction, a very unpleasant fetid odor, which is doubtless due to the organic matter which they contain, and before the discovery of their great value the negroes called them "stinking stones." But these stones are easily broken, and, indeed, are ground to a powder so fine that it floats upon the air. The land mines cover many hundred acres of ground; they are worked with picks and shovels. The whole tract has to be well and deeply trenched, and this is always done with reference to its natural drainage. Sometimes, however, all ordinary ditching proves inadequate, and the steam pump has to be continually used. The miners work in the trenches, a few feet apart, throwing the superincumbent earth behind them, and the phosphate rock in front. The rock when first taken from the earth is thickly coated with the sticky clay in which it has been embedded for centuries. It is then carried to the works, where it is subjected to a sledge moved by machinery, which breaks the nodules apart, and regulates their size, with very little pulverization. From this sledge they are passed into long washers, where a revolving shaft armed with steel teeth slowly moves the nodules up the inclined bed of the trough against copious descending streams of water. Or a cylindrical washer is used, to whose sides are attached spiral flanges of iron, and through whose axis runs a perforated pipe, which distributes a powerful stream of water. From the upper end of the "washer" the clean rock falls upon an iron grating; this separates the rock of a proper size from what is called "tailings." The rock is then spread in the sun to dry, or it is put in the drying shed. This shed is full of great iron pipes, perforated, so as to emit currents of hot air into every part of it.

The mining is done by negroes, although lately some companies have found it both necessary and profitable to import laborers. These imported laborers are mostly Italians.

The connecting link between the land and marine mining is called "hand picking." This work is done in rivers and creeks where dredges cannot conveniently be used. The negroes begin "picking" about two hours before low tide—the water being then waist deep—and they continue it until within two hours of high water. The rock is loosened with picks and crowbars, and then thrown into flat-bottomed boats; and it is quite possible for three or four workmen to fill a boat between the two tides. When the rock is too deep for picking, oyster-tongs are used, and not infrequently diving is necessary. Indeed, negroes will dive into water six to ten feet deep and bring to the surface in their hands masses of rock requiring two men to place them in the flats. Prof. Shephard, in speaking of this hand-picking at the confluence of the North and South Winbee Creeks, has a realistic picture of the water teeming with negroes, naked and vociferating, brandishing their tongs and poles, and swimming about or diving in the surrounding stream—the low, marshy banks dotted with palmetto clumps, sheltering at least 100 phosphate flats and forming the background to a picture highly suggestive of some of Stanley's African experiences.

Beyond these grounds, however, nature has still deeper and richer storehouses. But here man has to call in the aid of steam, and the deep water phosphate mines are worked by dredges. These dredges are flat-boats, 60 or 70 feet long, and drawing from $2\frac{1}{2}$ to $3\frac{1}{2}$ feet of water. They work best in about 12 feet of water, but have been successfully used in twice that depth. When at work, the dredge is kept in place by four posts called "spuds." These are dropped into the bed of the river, and they secure the boat by means of iron shoes, or caps, on their lower end. The dipper attached to the bow of the dredge is capable of raising 100 tons every day. It is lowered by steam, and its edge strikes the bed of the rock with such violence that it is driven pretty deeply into it. It is then drawn through the bed, tearing it up in its passage and filling itself as it proceeds. On being brought to the surface it empties itself by means of a hinged bottom upon a grating or into a preliminary "washer," where it is at once subjected to a large stream of water, which carries off the greater part of the mud, sand, oyster-shells, etc., that have been lifted with the nodules. After being "crushed" and again thoroughly "washed," they are taken off the dredges by lighters and conveyed to the drying-house.

Commercially, these phosphate rocks represent $5,000 a day to the city of Charleston, and the demand for the rock in its crude state is greater than the supply. Immense quantities in this condition are shipped not only to various parts of the United States but to many foreign ports, and undoubtedly its fame as a fertilizer will supersede all others in a very short time. Around Charleston are many large fertilizing works in which the phosphate rocks are ground to the finest imaginable powder. This powder is afterward mixed with fish-scrap and acids, and then put up in bags of 102 pounds each. In this form it is ready for the planter, and is again returned to the earth, causing the corn and the cotton, as the negroes say, "to lif' up de glad hand to God." It is worth noting that the development of these mines, which promise to be a real Southern bonanza, is due entirely to private enterprise and capital, and no one grudges to these adventurous workers the rich reward they are reaping.

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